Checklist for Today

• Things that were due Monday:
  - Chapter 8 Quizzes on WebCT

• Things due today:
  - Read Chapters 10 & 11

• Things that are due tomorrow in Recitation
  - Chapter 9 problems
The Schedule

This Week: (3/17)
- Chapter 8 quizzes due in WebCT
- Reading for Chapters 10 & 11
- Lecture on Chapter 10 (11 in recitation)
- Chapter 9 and Exam 2 Review in recitation

Next Week: (3/24)
- Chapter 9 due in WebCT (mini-practice exam 2 available)
- Exam 2 on Tuesday
- Recitation on Chapters 10 & 11
- Reading for Chapters 12 & 13 for Thursday
- Lecture 12 & 13 on Thursday

Following week
- Chapter 10 & 11 material in WebCT
- Reading: Chapters 14–16
- Lectures on 14–16 (Lectures 1 and 2 of Four)
- Recitation on Chapters 12 & 13
Chapter 10: Momentum

Want to deal with more complicated systems

• Collisions
• Explosions

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

- Different style than in the textbook
- 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!

\[ \vec{P} \, \text{system} = \sum m_i \vec{V}_i \]
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:

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

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

\[ = m\vec{a} \]

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 $dp/dt = 0$, $\rightarrow p = \text{constant}$

*Momentum doesn't change*

\[mv = m'v'\]

\[\text{momentum before} = \text{momentum after}\]
Conservation of Momentum

For a **system**, by Newton’s laws, \( \Sigma F = 0 \)

\[ \sum m_i \vec{v}_i = \sum m_i' \vec{v}_i' \]

Sum of all 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
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?
Everyday Experience?

**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 **ALWAYS** conserved for a **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 **making** it fall.
  - **Newton's Law**: For every action there is an equal and opposite reaction
- Add up all the momentums in the problem
  - The force>Error and the force(Error
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:
  \[
  \text{Inelastic} = \text{mechanical energy not conserved} = \text{kinetic energy not conserved}
  \]

- 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 $V_o$ 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...

• **Yesterday:** Chapter 8 quizzes in WebCT if you haven't finished them already
• **Tomorrow:** Recitation on Chapter 9 and exam review
• **Next Lecture:** Finish Chapter 10
• **Next week:**
  - Homework 9 due
  - Mini-practice exam 2 and bonus points
  - Exam 2, Tuesday March 25th
  - Start Chapters 12-16