Today’s Concept:

Conservation of Momentum

Inelastic Collisions
Where are we?

Mechanics Lecture 3, Slide 2

"rephrase" Newton’s Laws one more time
How to know if force is external or not

One of the toughest sections I ever came thru

I think the whole idea with center of mass was kinda math involved which made it difficult.

The ball bouncing off and sticking was a little confusing.

The kinetic energy thing, it was the only thing that confused me.

Box and ball was a tad bit confusing, may we further discuss it in class?

Everything

the box and ball collision had me stumped for a bit until i did some math

How to know when the collisions are elastic or inelastic.

I think this lesson is OK from a conceptual standpoint but it would help to see more examples of practice problems in a mathematical form that would help visualize and contextualize how to set up conservation of momentum equations to solve for a value faster/more confidently.

The momentum equations and their applications confused me.

Numerical practice problems to show how the laws work would be appreciated.
Suppose you drop a 1-kg rock from a height of 5 m above the ground. When it hits, what is the average force the rock exerts on the ground? (You may ignore air resistance.)

A. 0.2 N  
B. 5 N  
C. 50 N  
D. 100 N  
E. impossible to determine
What is the different between conservation of Momentum and conservation of energy? How do I know if the Momentum is conserve or energy is conserve?

Momentum (Unit 11)

\[ \text{Conservation of Momentum} \]

\[ \text{When } \vec{F}_{\text{Net, External}} = 0, \text{ then } \frac{d\vec{P}_{\text{Total}}}{dt} = 0 \rightarrow \vec{P}_{\text{Total}} = \text{Constant} \]

Energy (Unit 8)

\[ \Delta E_{\text{Mechanical}} = W_{\text{NC}} \]

\[ \text{Conservation of Mechanical Energy} \quad \Delta E_{\text{Mechanical}} = 0 \quad (\text{When work by non-conservative forces is zero}) \]
Question

A wood block rests at rest on a table. A bullet shot into the block stops inside, and the bullet plus block start sliding on the frictionless surface. When is the momentum of the bullet constant in the x direction?

A) Before the collision.
B) During the collision
C) After the collision
D) All of the above
E) Only A and C above

As long as there are no external forces acting on the system.
A wood block rests at rest on a table. A bullet shot into the block stops inside, and the bullet plus block start sliding on the frictionless surface. When is the momentum of the bullet plus block constant in the x direction?

A) Before the collision.
B) During the collision
C) After the collision
D) All of the above
E) Only A and C above

As long as there are no external forces acting on the system.
Recap

Total Momentum

\[ \vec{P}_{\text{Total}} = M_{\text{Total}} \vec{V}_{CM} \]

\[ \frac{d\vec{P}_{\text{Total}}}{dt} = \vec{F}_{\text{Net,External}} \]

Conservation of Momentum

When \( \vec{F}_{\text{Net,External}} = 0 \), then \( \frac{d\vec{P}_{\text{Total}}}{dt} = 0 \) \( \rightarrow \) \( \vec{P}_{\text{Total}} = \text{Constant} \)

\[ \vec{P}_{\text{tot}} = \sum_{i} m_{i} \vec{v}_{i} \]
Elastic Collisions

- Conservation of Linear Momentum
- Conservation of Mechanical Energy
  - Kinetic energy of the *system* is conserved *(most of the time)*
  - Kinetic energy of the individual bodies can change
- Ex: “Billiard Ball Collisions”

In-Elastic Collisions

- Mechanical Energy **NOT** conserved
- Conservation of Linear Momentum
- Loss of energy: sound, heat, etc
- Bodies stick together: “Completely In-elastic”
- Ex: “Lumps of Clay Collisions”
Example 11.1 (Car Collision)

A blue car with a mass of $m_c=438$ kg is moving east with a speed of 23 m/sec and collides with a purple 1237 kg truck moving south at 10 m/sec. After they collide and stick together, what is the magnitude and direction of velocity? (Ignore friction of the instant of the collision.)
A 2000kg pirate cannon shoots a 10kg cannon ball to the left at a velocity of 120m/sec.

What happens to the cannon?
Suppose you are on a cart initially at rest that rides on a frictionless track. If you throw a ball off the cart towards the left, will the cart be put into motion?

A) Yes, and it moves to the right.

The initial momentum of the system is equal to zero and it must stay that way. The cart will move to the right at a tiny displacement in terms of the momentum of the ball to compensate for it and cancel it out.
CheckPoint

Suppose you are on a cart which is initially at rest that rides on a frictionless track. You throw a ball at a vertical surface that is firmly attached to the cart. If the ball bounces straight back as shown in the picture, will the cart be put into motion after the ball bounces back from the surface?

A) Yes, and it moves to the right.
B) Yes, and it moves to the left.
C) No, it remains in place.
What we thought......

A) Yes, and it moves to the right.
B) Yes, and it moves to the left.
C) No, it remains in place.

A) both motions to the right
B) The ball moves to the right. Momentum has to be conserved so it moves left to compensate for it.
C) the cart will move to the right when throwing the ball to the left but when the ball hits the wall it will cancel it out.
Question

Suppose you are on a cart that is moving at a constant speed $v$ toward the left on a frictionless track. If you throw a massive ball straight up (relative to the cart), how will the speed of the cart change?

A) Increase
B) Decrease
C) Will not change

As long as there are no external forces acting on the system, $P_{total}$ is conserved.
Question

Two balls of equal mass are thrown horizontally with the same initial velocity. They hit identical stationary boxes resting on a frictionless horizontal surface. The ball hitting box 1 bounces back, while the ball hitting box 2 gets stuck.

Which box ends up moving faster?

A) Box 1  B) Box 2  C) same
What we thought......

Which box ends up moving faster?

A) Box 1  B) Box 2  C) same

A) The initial momentum of two balls are the same. From the Law of Conservation of Momentum, the ball bounces back for box 1. After the collision, the ball has negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to overcome the negative momentum to over
Two balls of equal mass are thrown horizontally with the same initial velocity. They hit identical stationary boxes resting on a frictionless horizontal surface. The ball hitting box 1 bounces back, while the ball hitting box 2 gets stuck.

Which box ends up moving faster?

A) Box 1     B) Box 2     C) same
Two equal-mass balls swing down and hit identical bricks while traveling at identical speeds. Ball A bounces back, but ball B just stops when it hits the brick. Which ball is more likely to knock the brick over?

A) A
B) B
C) They both have the same chance.
Suppose you are on a cart that is moving at a constant speed $v$ toward the left on a frictionless track. If you throw a massive ball straight up (relative to the cart), how will the speed of the cart change?

A) Increase  
B) Decrease  
C) Will not change

As long as there are no external forces acting on the system, $P_{\text{total}}$ is conserved.
A railroad hopper car has a mass of $4 \times 10^4$ kg when empty and contains $2 \times 10^4$ kg of coal. It was initially coasting along the track at 9 m/s when the bottom of the hopper opens and steadily releases all the coal onto a platform below the rails over a period of 4 seconds.

How fast is the hopper car traveling after all the coal is dumped?

A) faster than 9m/sec
B) 9m/sec
C) slower than 9m/sec
D) 0 m/sec
Example 11.4 (Cart hit on the head)

A 3kg cart is rolling along, minding its own business at 5m/sec when suddenly *(out of the blue!!!)* a 2kg mass drops on top of it and sticks.

What is the velocity of the two mass system after this collision?
A projectile of mass $m$ moving horizontally with speed $v$ strikes a stationary mass $M$ suspended by strings of length $L$. Subsequently, $m + M$ rise to a height of $H$.

Given $v$, what is the height $H$?
If $m$ and $M$ remain the same, but $v$ has a bigger value then calculated value of $H$ will:

a) get bigger
b) get smaller
c) remain the same
If \( v \) remains the same, but \( M \) (the mass of the block) gets a bigger value then calculated value of \( H \) will:

a) get bigger
b) get smaller
c) remain the same
Which quantities are conserved during the collision?

A) momentum
B) mechanical energy
C) both momentum and mechanical energy

\[ 0 + mv_\text{o} = (m+M)v_\text{f} \]
Which quantities are conserved after the collision

A) momentum
B) mechanical energy
C) both momentum and mechanical energy

\[ 0 + \frac{1}{2}(m+M)v_0^2 = (m+M)gH + 0 \]
A projectile of mass \( m \) moving horizontally with speed \( v \) strikes a stationary mass \( M \) suspended by strings of length \( L \). Subsequently, \( m + M \) rise to a height of \( H \).

Given \( v \), what is the height \( H \)?
A projectile of mass 0.1 kg moving horizontally with a speed $v_0$ of 250 m/sec. strikes a stationary mass 12 kg suspended by strings.

How high will the block rise? What is the height $H$?