

Physics 101: Lecture 11 Momentum and Impulse



Key Ideas

- Previous lectures: **Work-Energy**

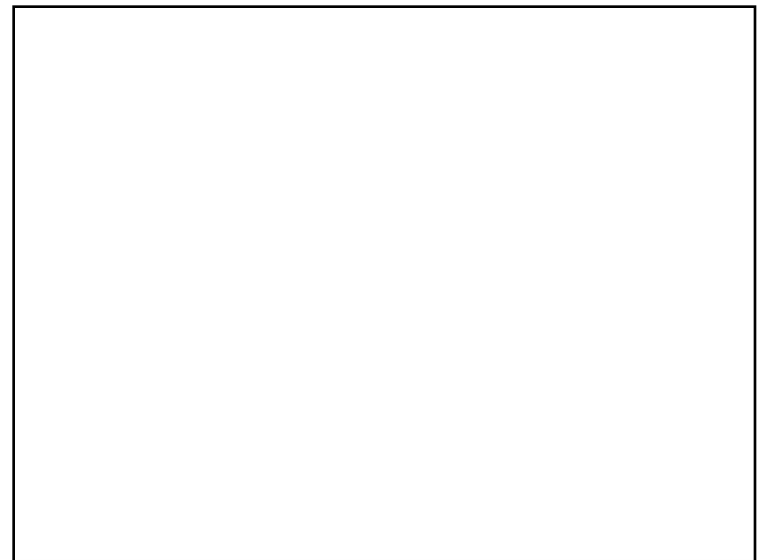
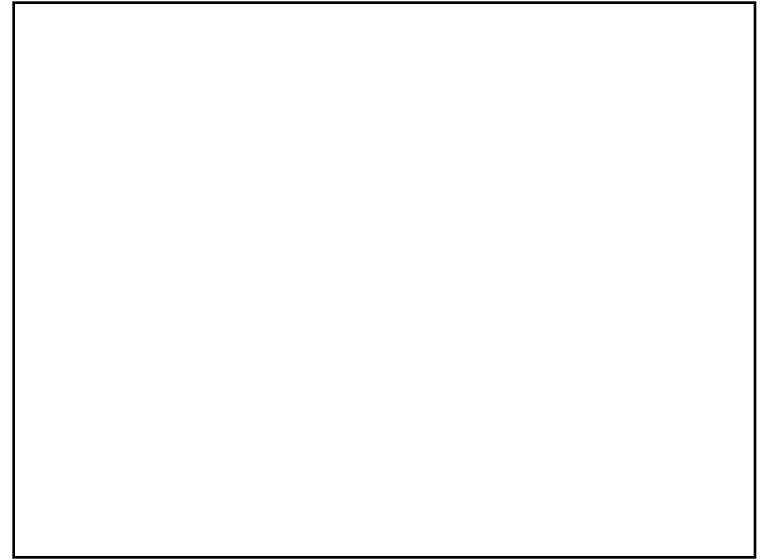
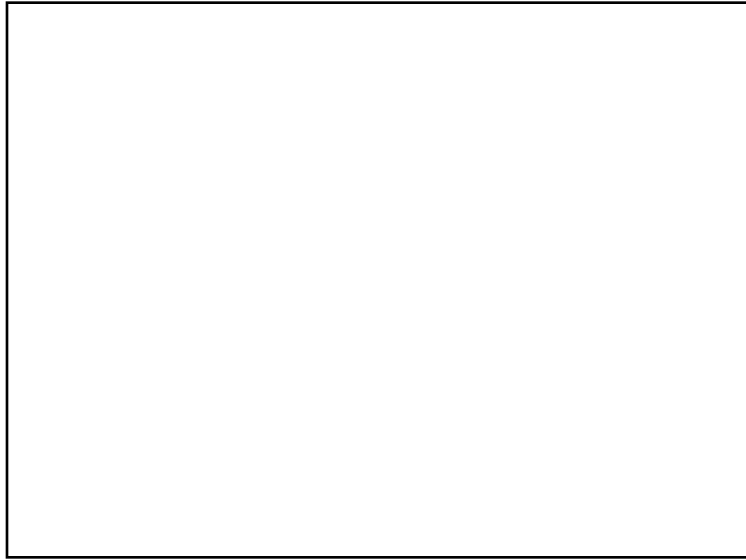
- $F_{\text{Net}} = m a$ multiply both sides by d
- $F_{\text{Net}} d = m a d$ (note: $ad = \frac{1}{2} \Delta v^2$ from $v^2 = v_0^2 + 2ad$)
- $F_{\text{Net}} d = \frac{1}{2} m \Delta v^2$
- **Work-Kinetic Energy Thm:**
 - » $W_{\text{Net}} = \Delta K$ OR $W_{\text{non-cons}} = \Delta E = \Delta(K + U)$

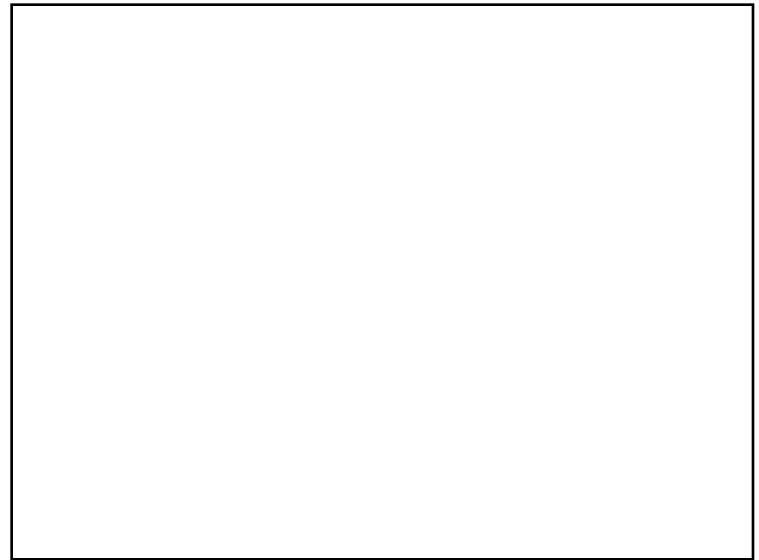
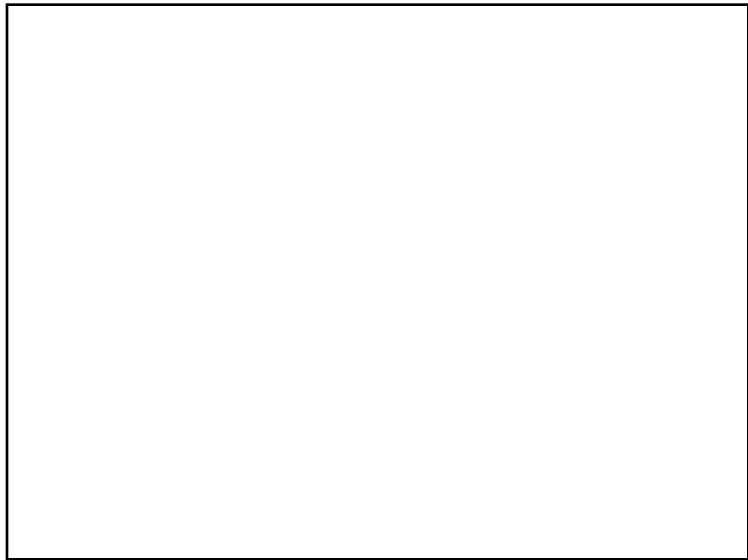
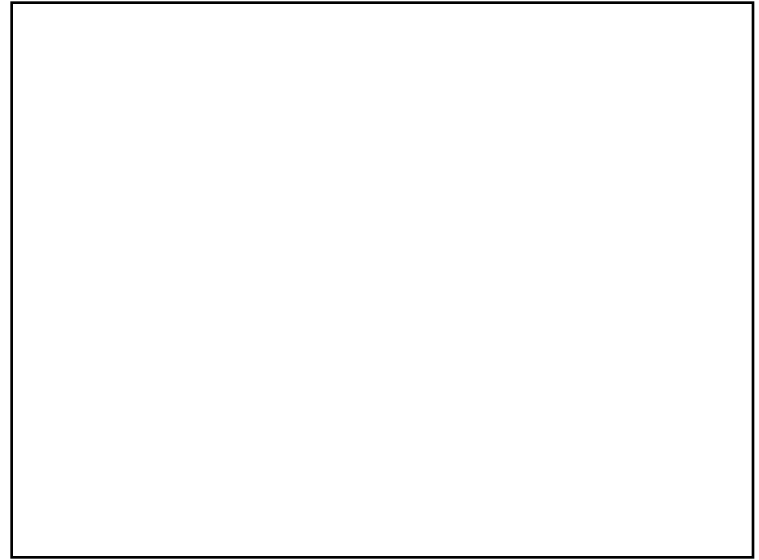
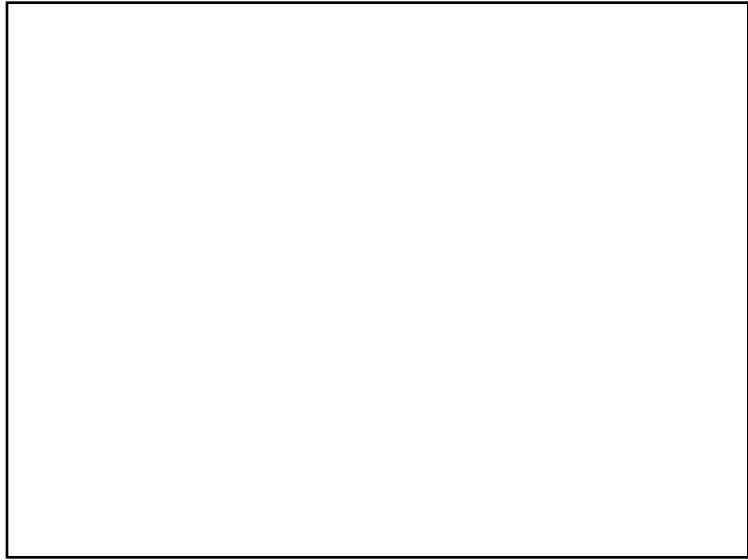
- This Time: **Impulse-Momentum**

- $F_{\text{Net}} = m a$
- $F_{\text{Net}} = m \Delta v / \Delta t$ (note: $a = \Delta v / \Delta t$)
- $F_{\text{Net}} = \Delta (mv) / \Delta t = \Delta p / \Delta t$
- $F_{\text{Net}} \Delta t = I_{\text{Net}} = \Delta p$ Define Impulse and Momentum

Momentum and Impulse

- **Momentum $p = mv$**
 - » Momentum is a VECTOR
- **Impulse-Momentum Thm: $I = F \Delta t = \Delta mv$**
 - » Impulse is = change in momentum: $I = \Delta p$
 - » Impulse is also a vector because F is a vector
 - » If there is no impulse, momentum does not change (i.e., it is conserved)
- ❖ **How to determine when momentum conserved?**
When no external forces cause an Impulse





Momentum is Conserved!

- Momentum is “Conserved” when there is **no external impulse**, meaning it cannot be created nor destroyed
 - ➔ Momentum can be transferred but if it is conserved, then $P_{\text{tot},i} = P_{\text{tot},f}$. Thus P_{tot} does not change with time *absent external forces*.
- Recall: Mech. Energy, $E=K+U$, conserved when there is **no external work** done on system).

These are 2 BIG IDEAS in physics

Impulse and Momentum Summary

$$F_{\text{Net}}\Delta t = \Delta p$$

- For single object....
 - ➔ $F_{\text{Net}} = 0 \Rightarrow$ momentum conserved ($\Delta p = 0$)
- For collection of objects ...
 - ➔ $F_{\text{Net}} = 0 \Rightarrow$ total momentum conserved ($\Delta P_{\text{tot}} = 0$)
 - ➔ If there is F_{Net} then there is impulse, and momentum is NOT conserved—it changes.

Example

A mother and a daughter are ice skating. The mother (mass $M=70$ kg) is skating at 5 m/s toward her stationary daughter (mass $m=40$ kg). When she reaches her daughter she bear-hugs her daughter and both slide off together. What is the common speed of the mother and daughter right after the collision?

Big Idea: Conservation of momentum

Justification: Force between mother-daughter are internal forces. Thus no external impulse so momentum is conserved.

Plan: 1) Conserve momentum by setting $P_{\text{tot},i}$ equal to $P_{\text{tot},f}$
2) Find the common speed of both after collision

Execution of plan:

1) $P_{i,\text{tot}} = P_{f,\text{tot}}$

2) $MV + m(0) = (M+m)V_{\text{final}}$

$(70 \text{ kg})(5 \text{ m/s}) + 0 = (70 \text{ kg} + 40 \text{ kg}) V_{\text{final}}$

Solve for V_{final} :

$V_{\text{final}} = 3.18 \text{ m/s}$

What would change if the daughter had been initially moving toward mom

Summary

➔ Impulse $I = F\Delta t$

» Gives change in momentum $I = \Delta p$

➔ Momentum $p = mv$

» Momentum is VECTOR

» Momentum is conserved (when $F_{\text{Net}} = 0$, since there is no impulse to change momentum)

■ $\Sigma mv_{\text{initial}} = \Sigma mv_{\text{final}}$