Physics 101: Lecture 11
Momentum and Impulse

Key Ideas

- Previous lectures: Work-Energy
  - $F_{Net} = m\,a$ multiply both sides by d
  - $F_{Net}\,d = m\,a\,d$ (note: $ad = ½\,\Delta v^2$ from $v^2 = v_o^2 + 2ad$)
  - $F_{Net}\,d = ½\,m\,\Delta v^2$
  - Work-Kinetic Energy Thm:
    - » $W_{Net} = \Delta K$ OR $W_{non\text{-}cons} = \Delta E = \Delta(K + U)$
- This Time: Impulse-Momentum
  - $F_{Net} = m\,a$
  - $F_{Net} = m\,\Delta v/\Delta t$ (note: $a = \Delta v/\Delta t$)
  - $F_{Net} = \Delta\,(mv)/\Delta t = \Delta p/\Delta t$
  - $F_{Net}\,\Delta t = I_{Net} = \Delta p$ Define Impulse and Momentum

Momentum and Impulse

- Momentum $\mathbf{p} = m\mathbf{v}$
  - » Momentum is a VECTOR
- Impulse-Momentum Thm: $\mathbf{I} = \mathbf{F}\Delta\mathbf{t} = \Delta m\mathbf{v}$
  - » 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 $P_{tot,i} = P_{tot,f}$. 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

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

- For single object….
  - $F_{Net} = 0 \Rightarrow$ momentum conserved ($\Delta p = 0$)
- For collection of objects …
  - $F_{Net} = 0 \Rightarrow$ total momentum conserved ($\Delta P_{tot} = 0$)
  - 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 $P_{tot,i}$ equal to $P_{tot,f}$

2) Find the common speed of both after collision

Execution of plan:

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

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

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

Solve for V_{final}:

$V_{final} = 3.18$ 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 $F_{Net} = 0$, since there is no impulse to change momentum)
    - $\Sigma\, mv_{initial} = \Sigma\, mv_{final}$