• C5 – Applying Momentum Conservation
Volunteer Opportunity - starts soon

- Lego Mindstorm NXT robots - no previous experience needed!
- Satisfy education volunteer hours
- Middle school age kids
- Three opportunities
  - Monday mornings at Siena - going on now
  - Saturdays - urban scholars - starts in Oct.
  - After school programs in Albany schools
    - Two days per week ~ 2 hrs per day
- You will be trained at Siena and you will be helping a teacher
- Contact Michele McColgan - mmccolgan@siena.edu
- Announcement on Blackboard
Tips on Maximizing your homework scores

• Review the instructions on setting up a problem
  • From today’s lecture – new framework
  • From the first lecture slides: find, given, box answers, etc.
• If I need to read the question in the book while I’m reviewing your HW, you’ll lose points, especially on WH
• Units!
• Direction for vector quantities!
• Do corrections!
• Collaborate with other classmates!
• Get help
  • Office hours T, TH 10 am- 12 pm, virtual S 8 – 9 pm
  • Schedule an appointment, send me an email
  • Tutoring S – Th evenings 8 – 11 pm in RB 150
Momentum conservation without isolation

- In chapter 4 we learned that in order for momentum to be conserved, the system had to be isolated from external interactions.
- Consider a cart collision
  - It’s obviously not isolated from external interactions
    - LR gravitational interaction, contact compression interaction
Gravity and compression interactions cancel

- The gravitational interaction and the compression interaction cancel
- The system **ACTS** like it’s isolated
Degrees of Isolation

- floats in space
- functionally isolated
- collision – momentarily isolated
Floats in space

- Both the system and the frame float freely in space and respond gravitationally to the same distant bodies.

- Examples
  - two stars in deep space
  - Earth and earth’s satellite
Functionally Isolated

- A system whose external interactions cancel
- The most common systems
  - Gravity and compression interactions cancel
- Examples – Why are these functionally isolated?
  - Books on a table
  - Cars driving down the road
  - Hockey pucks on ice
  - Billiard balls on pool table
A collision is any process where two system objects interact
  • for a short time
  • And delivers an impulse much larger than any other interaction during that time
• External interactions don’t have time to transfer significant momentum to the system.
• Examples
  • Collisions
  • Explosions
Are these systems isolated? How?

- Space shuttle and its contents
- Two billiard balls that collide
- Two magnetic hockey pucks that change each other’s paths in a hockey game
- Exploding fireworks
- Two cars skidding on a road hit each other
Problem solving framework

- Translate the problem into mathematical symbols
  - Pictures are VERY important
- Build conceptual model linking physics equations
- Work out algebraic solution
- Evaluate (check) your results to see if they make sense

- Review p. 86 – 91!!!
Translate

- Given:
- Find:
- Draw a picture
- Define reference frame axes
Conceptual Model

- What theories/principles apply
- Simplifications/Assumptions
- Select equations to develop a coherent and reasonable plan to solve problem
- Most important step
  - Requires 90% of thinking to accurately solve problem!
Algebra

- Solve equations symbolically
- Don’t plug numbers in until the last step
- Keep track of units
  - Great way to check if answers are reasonable
Evaluate

- Do the numbers make sense?
  - Are the units correct?
  - Are the signs (direction) and magnitudes correct?
Model diagrams

- Helping diagram
- Master equation
- Physical principle – why it applies
- Identify symbols that are zero or that cancel
- Circle unknown symbols
- Identify other needed equations
- Repeat until solved
Master equation for conservation of momentum

- $p_i = p_f$
Conservation of Momentum

- The total momentum of a *system* is constant.
- For collisions, use
  \[ \vec{p}_{\text{before}} = \vec{p}_{\text{after}} \]
  \[ \vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f} \]
- In component form, the total momenta in each direction are independently conserved
  \[
  m_0 \begin{bmatrix} v_{0x} \\ v_{0y} \\ v_{0z} \end{bmatrix} = m_A \begin{bmatrix} v_{Ax} \\ v_{Ay} \\ v_{Az} \end{bmatrix} + m_B \begin{bmatrix} v_{Bx} \\ v_{By} \\ v_{Bz} \end{bmatrix}
  \]
Exploding spaceship – example C5.1

- A 10,000-kg spaceship in deep space travels at 40 kms toward the Andromeda galaxy. Its engines suddenly explode, blowing the ship apart into two hunks. The front (8000-kg) hunk continues moving toward Andromeda at 60 km/s. What is the velocity (magnitude and direction) of the back hunk?
Solution

Translation

Initial:

Final:

Known:
\[ m_0 = 10,000 \text{ kg} \]
\[ m_A = 8000 \text{ kg} \]
\[ v_0 = 40 \text{ km/s} \]
\[ v_A = 60 \text{ km/s} \]

Conceptual Model Diagram

Assume that the fragments have the same total mass as the ship

\[ \begin{align*}
\begin{bmatrix}
  m_0 \\
  0 \\
  0 \\
\end{bmatrix}
  &=
  \begin{bmatrix}
    m_A \\
    0 \\
    0 \\
  \end{bmatrix}
  =
  \begin{bmatrix}
    v_{Bx} \\
    v_{By} \\
    v_{Bz} \\
  \end{bmatrix}
  \\
  m_0 &= m_A + m_B
\end{align*} \]

(4 equations, 4 unknowns)
A 1000-kg car traveling west at 20 m/s collides with an 800-kg car traveling north at 16 m/s. The collision locks the cars together. What is the velocity of the two-car unit just after the collision? Include magnitude and direction angle.
Solution - 1

Translation

Initial:

Final:

Known:

\( m_1 = 1000 \text{ kg} \)
\( m_2 = 800 \text{ kg} \)
\( v_1 = 20 \text{ m/s} \)
Solution - 2

Conceptual Model Diagram

\[ m_1 \begin{bmatrix} -v_1 \\ 0 \\ 0 \end{bmatrix} + m_2 \begin{bmatrix} 0 \\ +v_2 \\ 0 \end{bmatrix} = \begin{bmatrix} m_f \\ v_{fx} \\ v_{fy} \\ v_{fz} \end{bmatrix} \]

\[ \text{CoM: collision} \]

\[ \text{mag}(\vec{v}) = \sqrt{v_{fx}^2 + v_{fy}^2 + v_{fz}^2} \]

Assumes cars haven't shed pieces

\[ \theta = \tan^{-1} \left( \frac{v_{fx}}{v_{fy}} \right) \]

\[ \text{trig} \]
Examples

- Kim holds a 2.0 kg air rifle loosely and fires a bullet of mass 1.0 g. The muzzle velocity of the bullet is 150 m/s. What is the recoil speed of the rifle?
Suppose two clowns on skateboards are standing motionless on a smooth surface 2.0 m apart. Clown B tosses a 5.0 kg medicine ball to clown A. The medicine ball is traveling with a speed of 10. m/s.

- What is the resulting velocity of **clown B** after catching the ball? (Be sure to indicate which direction is positive.)