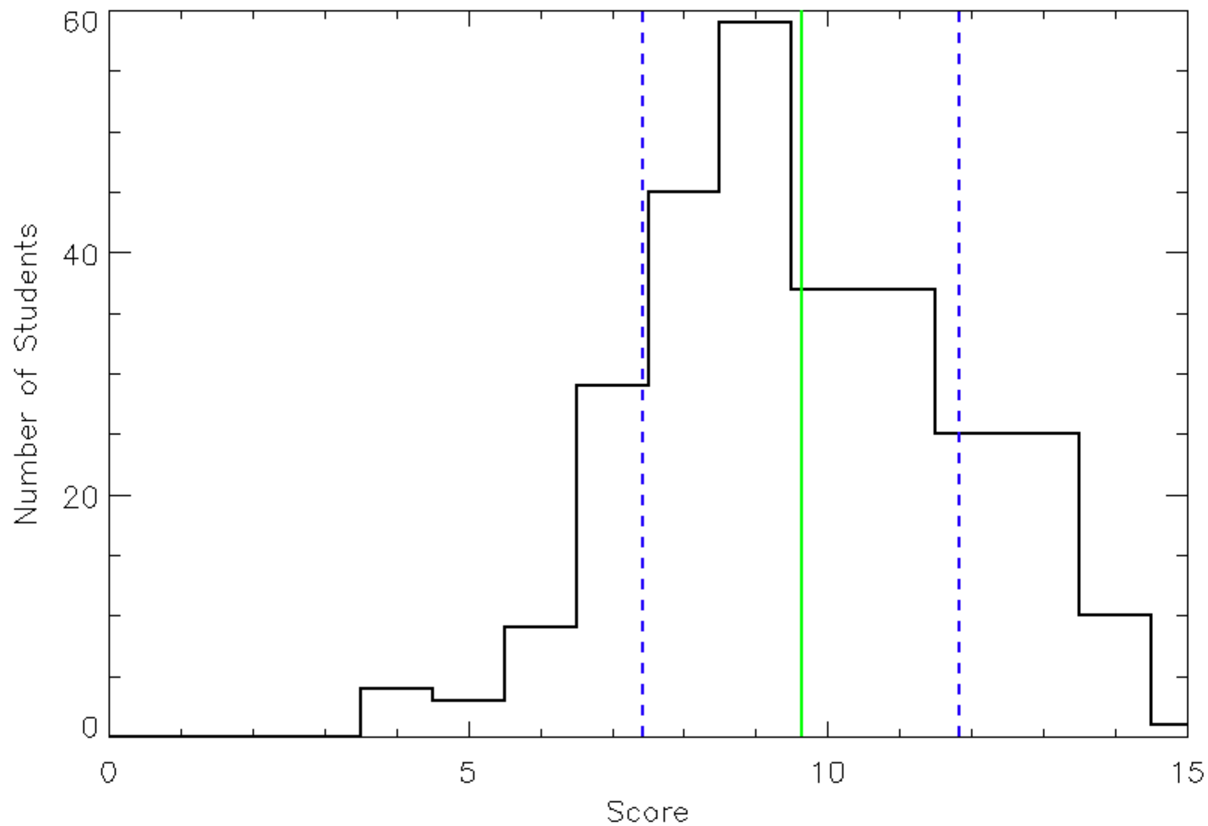
College Physics I: 1511 Mechanics & Thermodynamics

Professor Jasper Halekas
Van Allen Lecture Room 1
MWF 8:30-9:20 Lecture

Exam Debrief

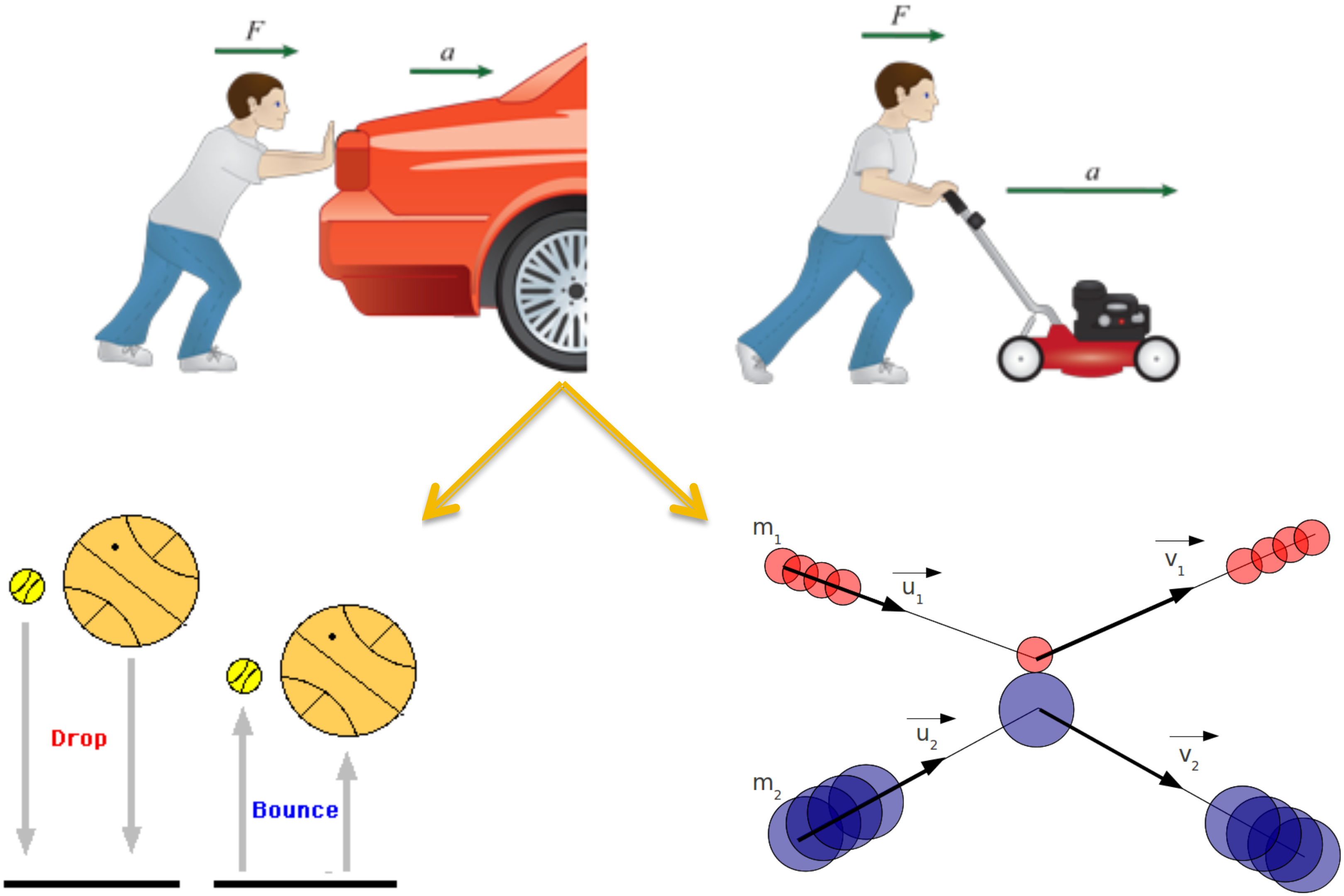
- Mean = 9.63/15 = 64%   (> 60% target!)
- Std. Dev. = 2.22
- Min =4
- Max = 15
- Nice job!!!!
- Solutions posted tonight



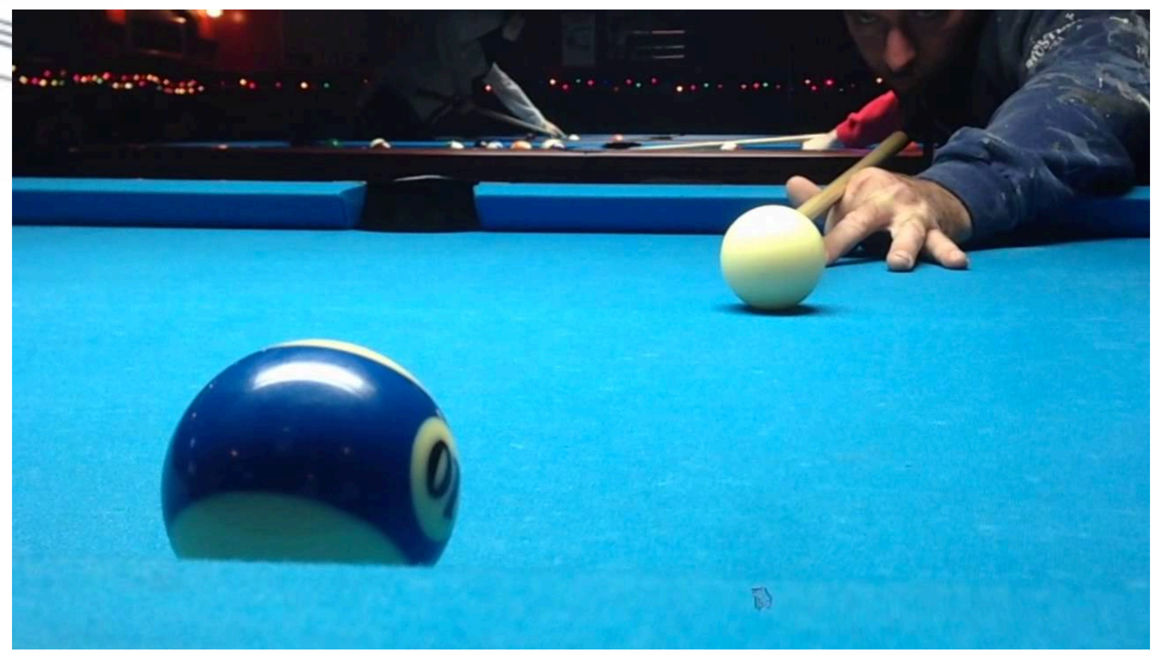
Announcements

- Homework due Thursday night as usual
- Labs scheduled as usual

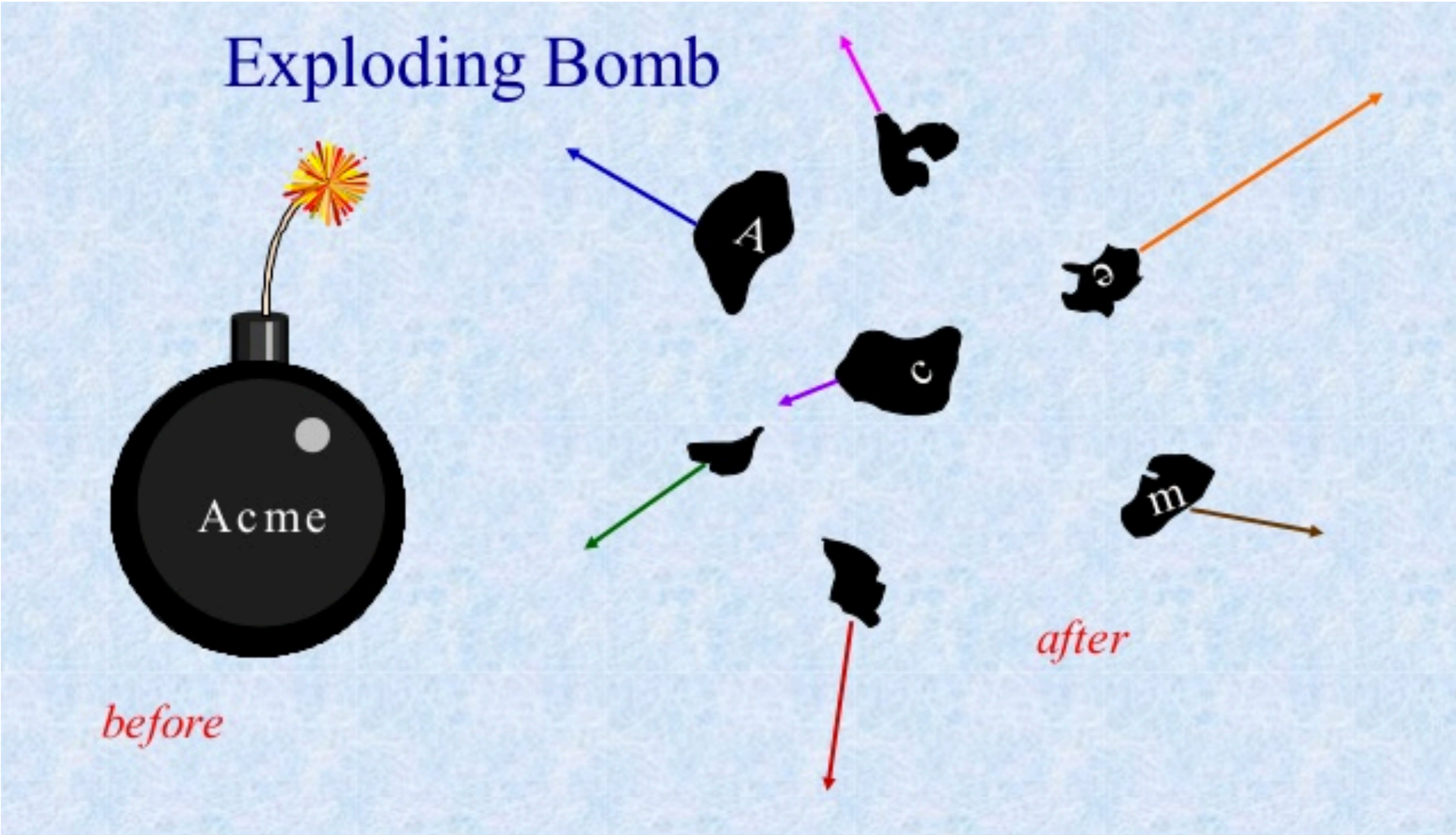
New Concepts Today



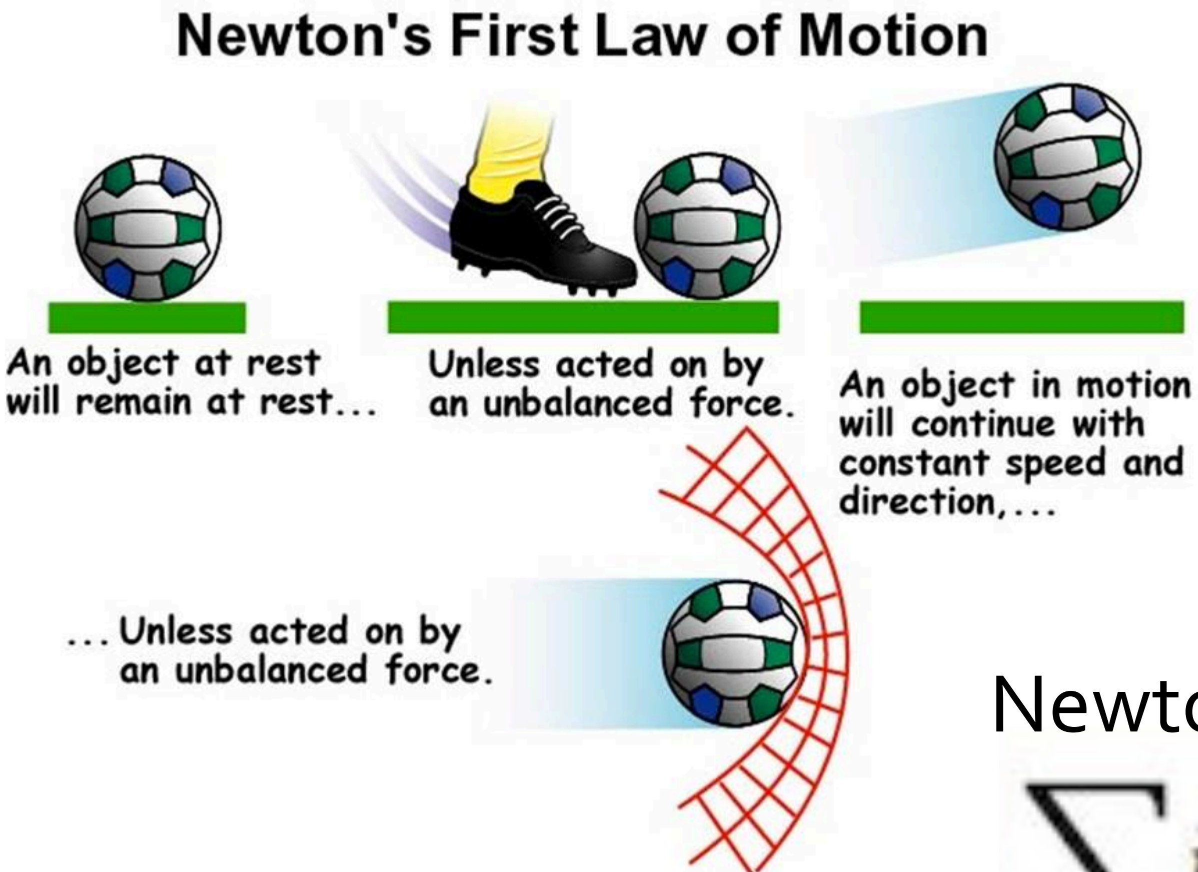
Collisions



Explosions



Newton’s First Two Laws (Again!)



Newton’s Second Law

$$\sum \vec{F} = m \cdot \vec{a}$$

$$\Sigma \vec{F} = m\vec{a}$$

$$= m \, \Delta\vec{v} / \Delta t$$

$$= m(\vec{v}_f - \vec{v}_i) / \Delta t$$

$$= (m\vec{v}_f - m\vec{v}_i) / \Delta t$$

$$\Rightarrow \Sigma \vec{F} \Delta t = m\vec{v}_f - m\vec{v}_i$$

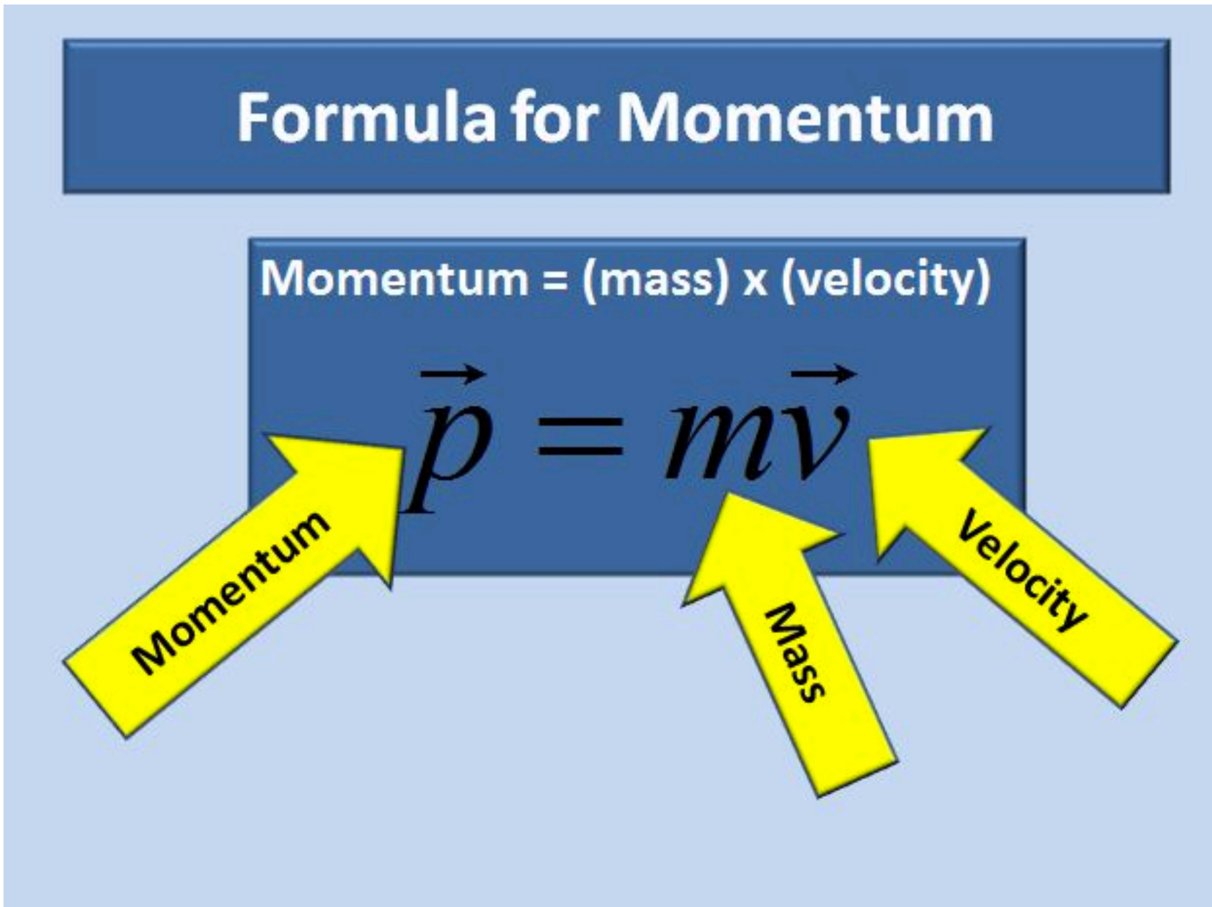
Impulse = change in momentum

Impulse-Momentum Theorem

$$\vec{F} \cdot \Delta t = m\vec{v}_f - m\vec{v}_i$$

$$= \Delta\vec{p}$$

Definition: Momentum



SI Units [kg][m]/[s] (no special name)

Definition: Impulse

$$\text{Impulse} = \text{Force} \times \text{time} = \vec{F}\Delta t$$

$$\Delta t = t_{final} - t_{initial}$$

SI Units [N][s] = [kg][m]/[s]
(same as momentum)

Concept Check

- One glass beaker is dropped from rest onto a piece of foam, and a second is dropped from rest from the same height onto a brick. Neither one bounces. Which beaker experiences the highest maximum force?
  - A. The beaker dropped on foam
  - B. The beaker dropped on bricks
  - C. Both experience the same force
  - D. Impossible to determine

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$\Delta \vec{p}$ same for both

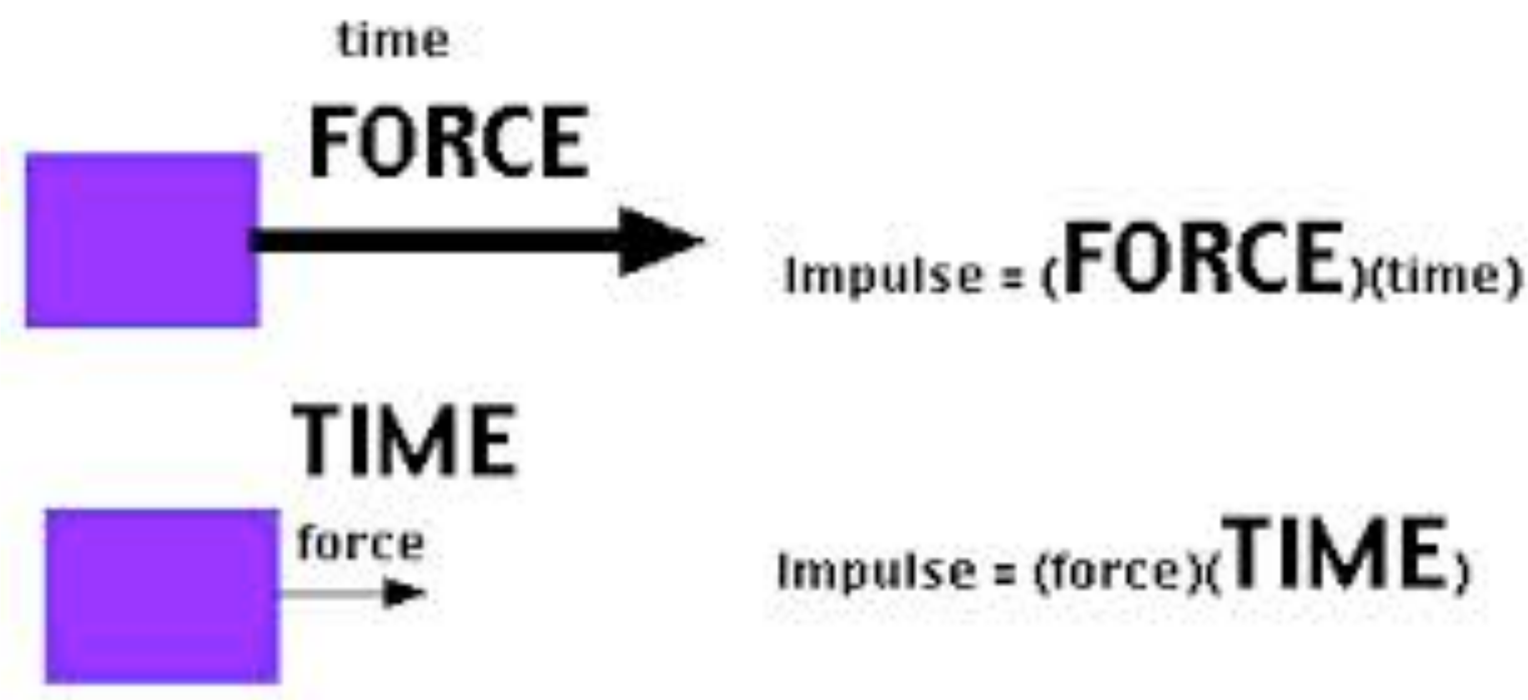
$m\vec{v}_o$ same

$m\vec{v}_f = 0$

so $\vec{F}\Delta t$ same

Foam has longer Δt,
so lower $\vec{F}$

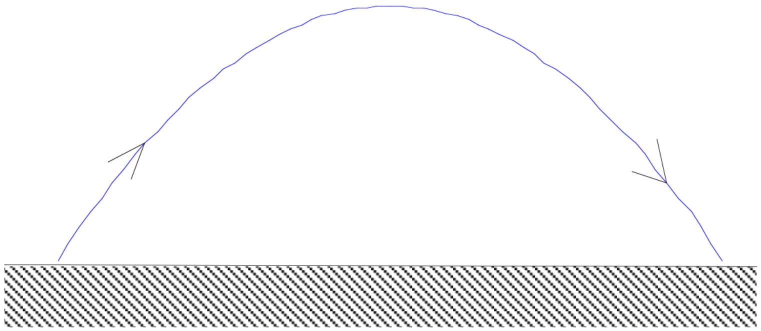
Impulse-Momentum



Crumple Zones

Concept Check

A projectile is fired with initial speed v_o at an angle of 45^o above the horizontal. Assume no air resistance.



i: During the flight, the x-component of the projectile's momentum remains constant.

ii: During the flight, the y-component of the projectile's momentum remains constant.

A) i is True and ii is True
B) i is True and ii is False
C) i is False and ii is True
D) i is False and ii is False

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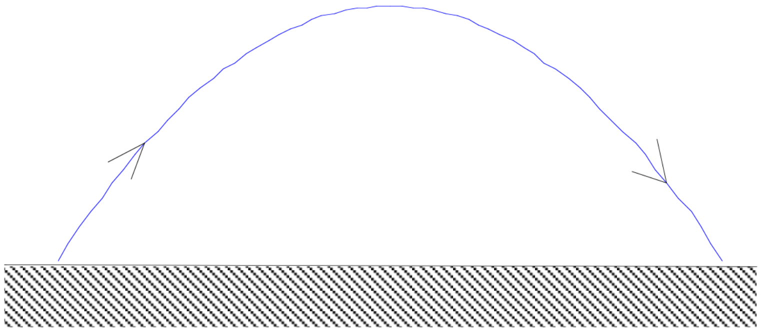

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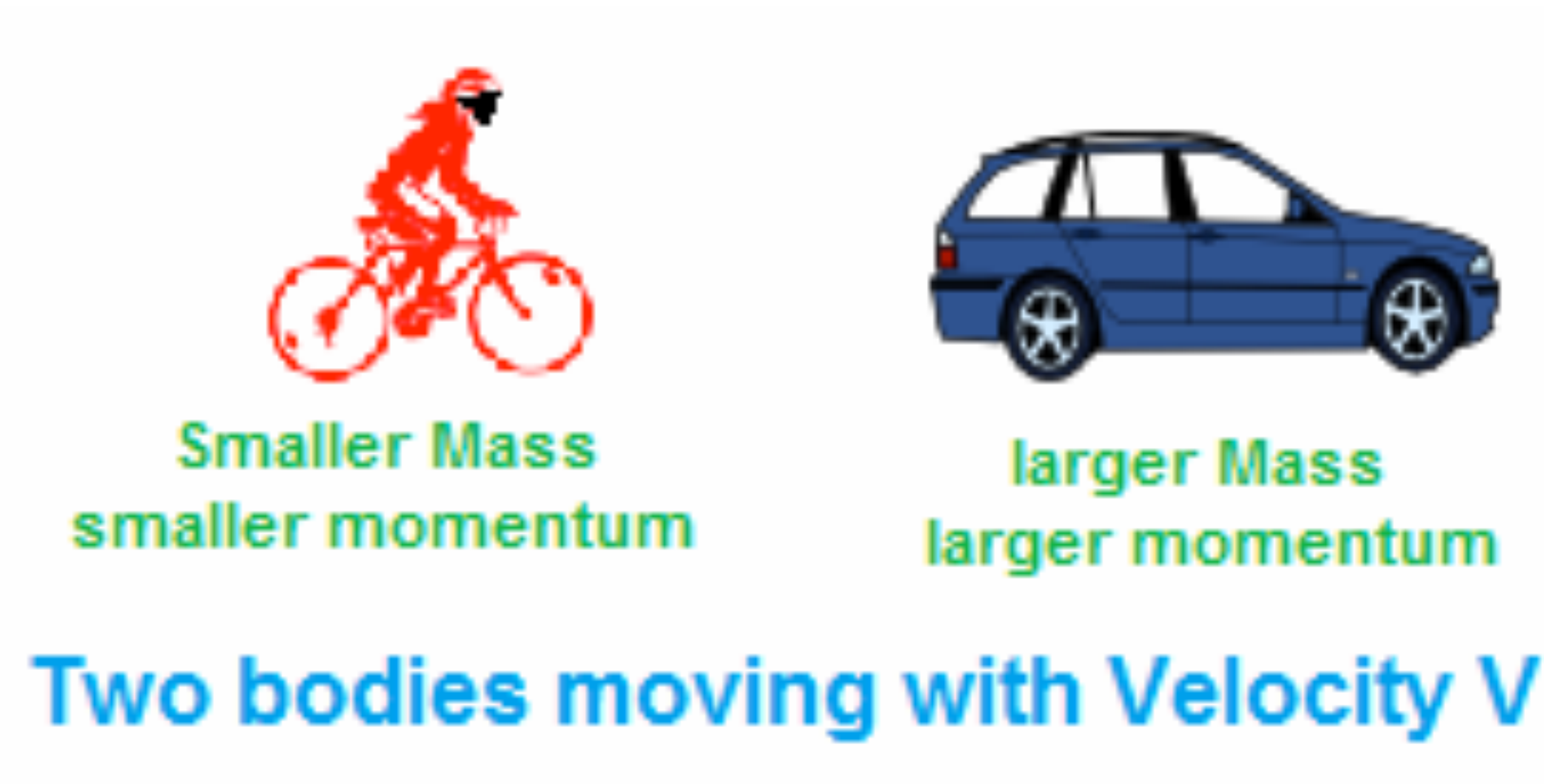
Why momentum instead of velocity?



Bigger objects require more force to change their velocity!

Why momentum instead of energy?

- Sometimes momentum is conserved even when mechanical energy is not!
- Momentum is often more useful when considering multiple bodies simultaneously

Impulse momentum for two bodies:

$$\sum \vec{F}_1 \Delta t = \vec{p}_{1f} - \vec{p}_{1i}$$

$$\sum \vec{F}_2 \Delta t = \vec{p}_{2f} - \vec{p}_{2i}$$

Say all forces balanced except those between the two objects:

$$\sum \vec{F}_1 = \vec{F}_{12}$$

$$\sum \vec{F}_2 = \vec{F}_{21}$$

$$\vec{F}_{12} \Delta t = \vec{p}_{1f} - \vec{p}_{1i}$$
$$\vec{F}_{21} \Delta t = \vec{p}_{2f} - \vec{p}_{2i}$$

Add together

$$(\vec{F}_{12} + \vec{F}_{21}) \Delta t = \vec{p}_{1f} - \vec{p}_{1i} + \vec{p}_{2f} - \vec{p}_{2i}$$

↑ 0 by Newton's 3rd

$$\vec{p}_{1f} - \vec{p}_{1i} + \vec{p}_{2f} - \vec{p}_{2i} = 0$$

or $\vec{p}_{1f} + \vec{p}_{2f} = \vec{p}_{1i} + \vec{p}_{2i}$

True if no net external force

If external forces are present:

$$(\vec{F}_{1ext} + \vec{F}_{12})\Delta t = \vec{p}_{1f} - \vec{p}_{1i}$$

$$(\vec{F}_{2ext} + \vec{F}_{21})\Delta t = \vec{p}_{2f} - \vec{p}_{2i}$$

$$(\vec{F}_{1ext} + \vec{F}_{2ext})\Delta t = \vec{p}_{1f} - \vec{p}_{1i} + \vec{p}_{2f} - \vec{p}_{2i}$$

- Under net external force, the total momentum is not conserved

Conservation of Momentum

- Consider two bodies subject to both external and internal forces
  - "Internal forces" = forces between the two bodies (e.g. $\mathbf{F}_{12}$ = Force on body 1 from body 2)

- $(\mathbf{F}_{1ext} + \mathbf{F}_{12})\Delta t = \mathbf{p}_{1f} - \mathbf{p}_{1i}$
- $(\mathbf{F}_{2ext} + \mathbf{F}_{21})\Delta t = \mathbf{p}_{2f} - \mathbf{p}_{2i}$

- $(\mathbf{F}_{1ext} + \mathbf{F}_{2ext} + \mathbf{F}_{12} + \mathbf{F}_{21})\Delta t = \mathbf{p}_{1f} - \mathbf{p}_{1i} + \mathbf{p}_{2f} - \mathbf{p}_{2i}$

Note: All bolded letters represent vectors!

Conservation of Momentum

- $(\mathbf{F}_{1ext} + \mathbf{F}_{2ext} + \mathbf{F}_{12} + \mathbf{F}_{21})\Delta t = \mathbf{p}_{1f} - \mathbf{p}_{1i} + \mathbf{p}_{2f} - \mathbf{p}_{2i}$
- Simplify by using Newton's 3rd law and combining external forces and momenta to find:
- $\mathbf{F}_{ext\_total}\Delta t = \mathbf{p}_{f\_total} - \mathbf{p}_{i\_total}$
- If no net external force, total momentum of the two bodies is conserved
  - This can be extended to any number of bodies!

Conservation of Momentum

- Explicit expression for conservation of momentum for two bodies:
  - $m_1\mathbf{v}_{1f} + m_2\mathbf{v}_{2f} = m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i}$
  - True as long as no net external force acts
  - True even if total mechanical energy is not conserved!
    - In other words, the forces between the two bodies can be non-conservative, and this equality still holds

Concept Check

- A firework shell is launched at an angle, and just as it reaches the top of its trajectory (at which point it has speed V - all in the horizontal direction) it explodes into two pieces, each with half of the original mass. One fragment is observed to fall vertically down from the point of explosion.

- What does the other piece do?

A. Also falls vertically down
B. Recoils backwards from the explosion
C. Continues forward with the same speed (V) it had just before.
D. Continues forward with twice the speed (2V)
E. There can't possibly be enough information to decide.

Hint: Consider the motion immediately after the explosion, not the subsequent acceleration due to gravity.

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$$p_{ix} = mv$$

$$p_{fx} = m/2 \cdot 0 + m/2 \cdot v_2$$

$$= m/2 \cdot v_2$$

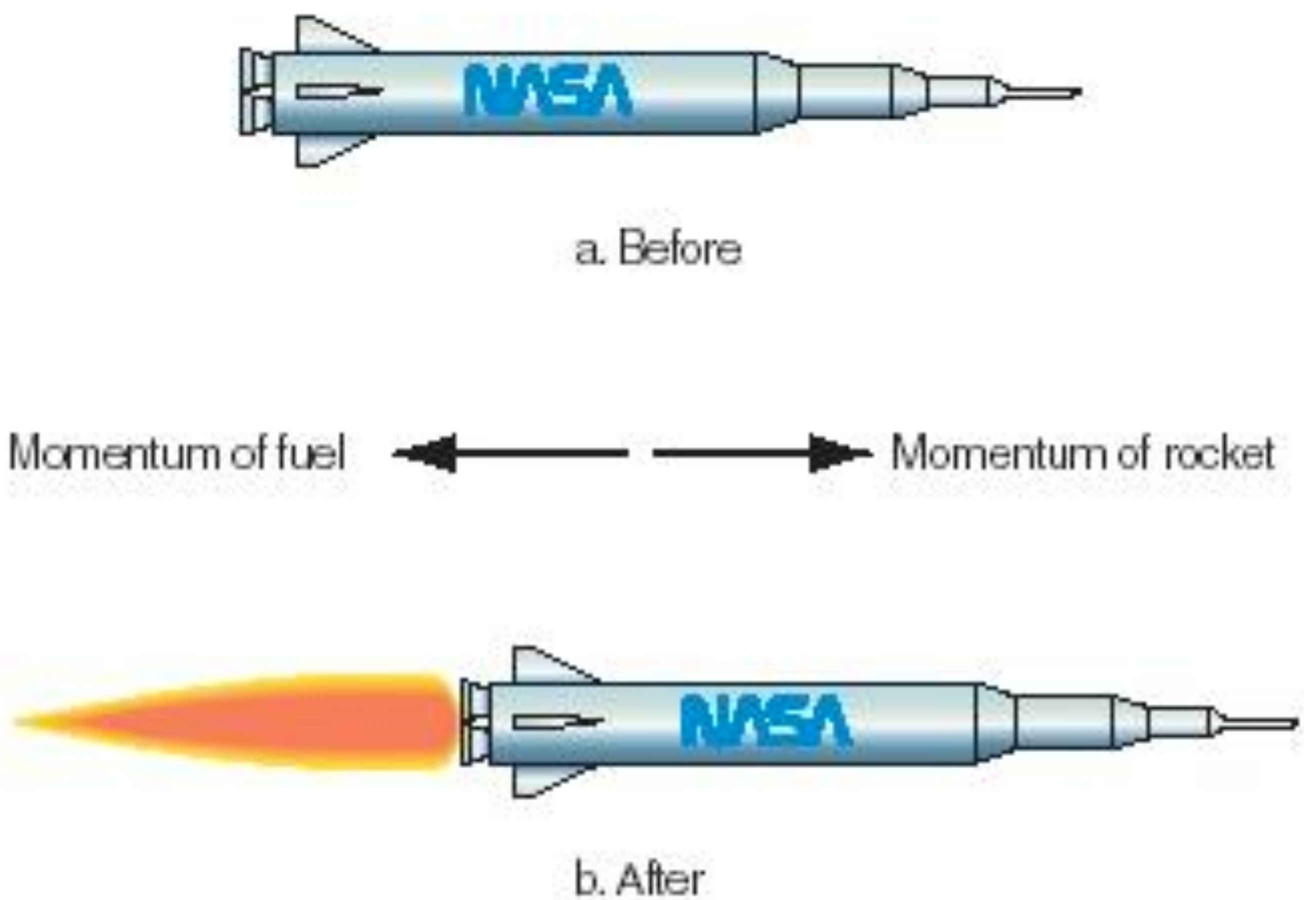
$p_{fx} = p_{ix}$ since no F_x

so $mv = m/2 \cdot v_2$

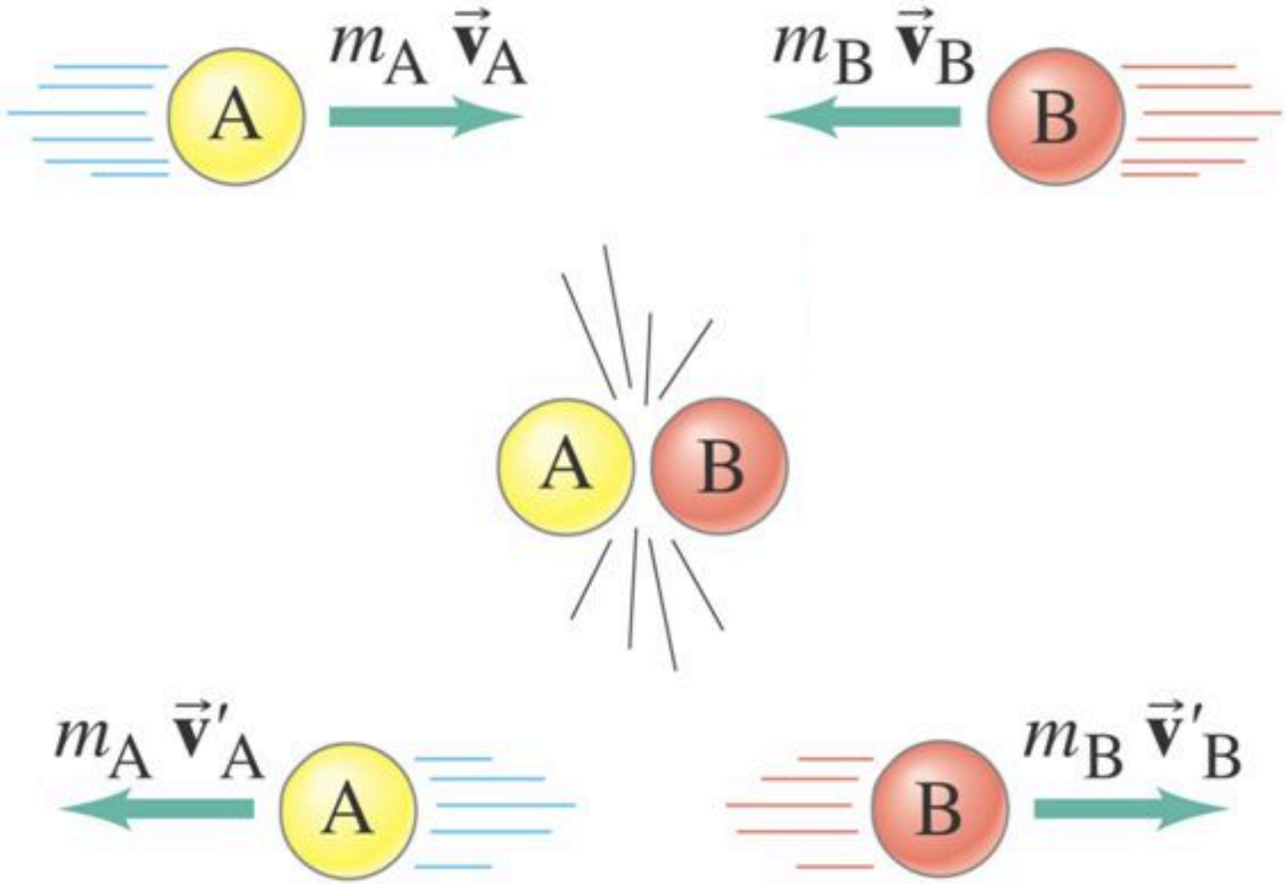
$$v = 1/2\, v_2$$

$$\boxed{2v = v_2}$$

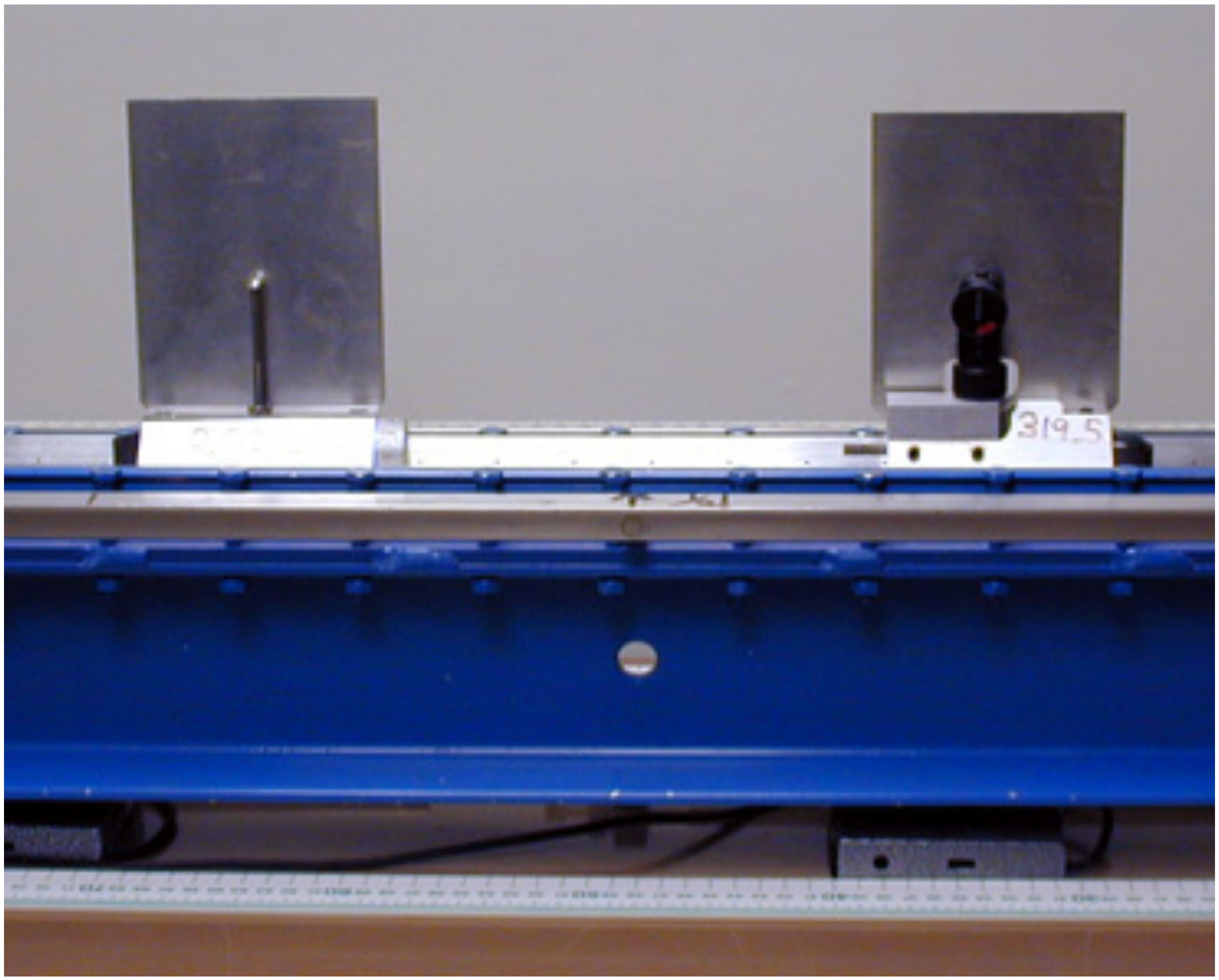
Rockets and Conservation of Momentum



Collisions: How to Solve?



Collisions With Different Mass Ratios



Definition: Types of Collisions

- Elastic collisions
  - Kinetic energy is conserved
    - Corresponds to objects that bounce perfectly
- Inelastic collisions
  - Kinetic energy is not conserved
    - Corresponds to objects that don’t bounce perfectly
- Totally Inelastic Collisions
  - Corresponds to objects that stick together after colliding