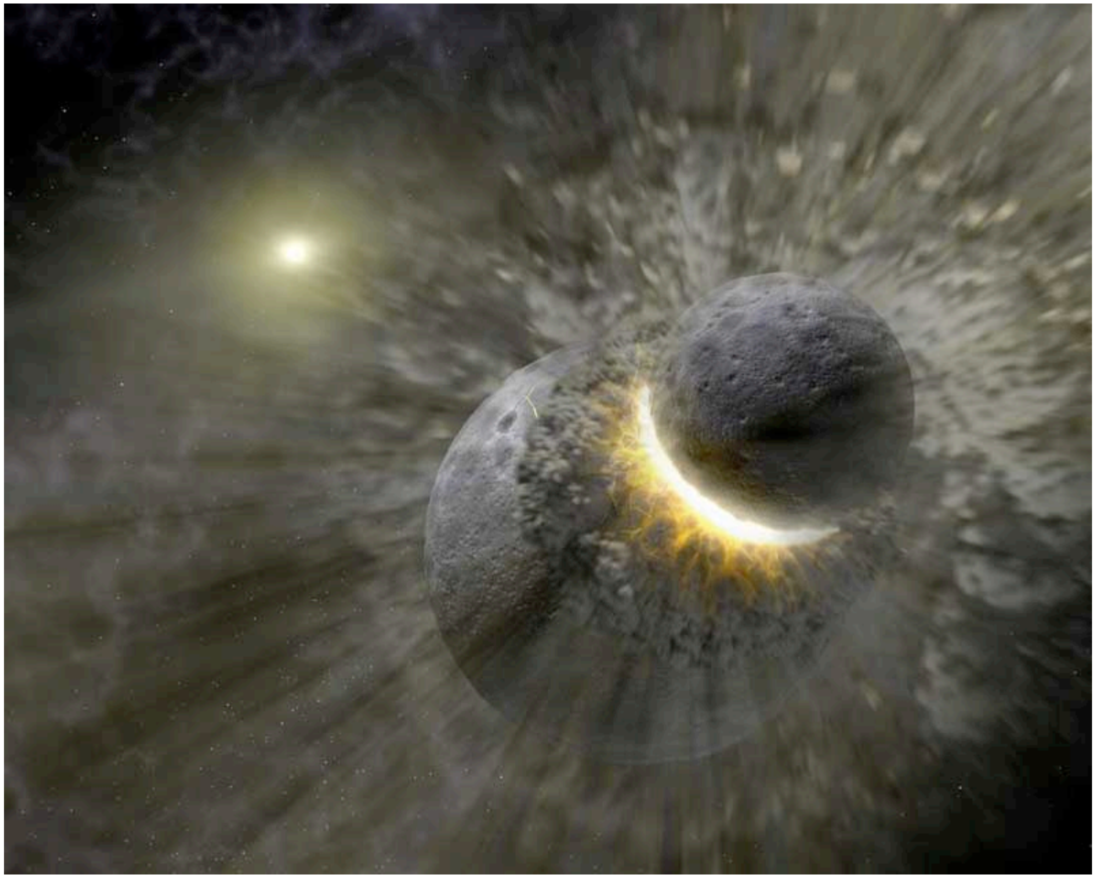
Physics 140 – Fall 2007
lecture #12: 11 Oct

<u>Ch 8 topics:</u>

- momentum
- impulse
- collisions in one dimension



Source: NASA/JPL-CalTech

Momentum

An object's ***linear momentum*** (denoted $\boldsymbol{p}$) is a vector quantity equal to the product of its mass and velocity

$$\boldsymbol{p} = m\,\boldsymbol{v}$$

The *total linear momentum* (denoted $\boldsymbol{P}$) of a system of two objects is the vector sum of the pair's individual values

$$\boldsymbol{P} = m_1\boldsymbol{v}_1 + m_2\boldsymbol{v}_2 = \boldsymbol{p}_1 + \boldsymbol{p}_2$$

For a system of N objects (or particles), simply extend the vector sum

$$\vec{P} = \sum_{i=1}^{n} m_i \vec{v}_i = \sum_{i=1}^{n} \vec{p}_i$$

Impulsive Encounters

When a force ***F*** ***acts abruptly*** for a short time Δt on an object (*e.g.*, a baseball struck by a swung bat), we define the ***impulse, J***, of the encounter as

$$\boldsymbol{J} = \boldsymbol{F}\Delta t$$

(When ***F*** is not constant, the impulse is the integral $J = \int F dt$)

The effect of an impulsive encounter is to ***change the object's momentum by the impulse***

$$\Delta \boldsymbol{p} = \boldsymbol{F}\Delta t = \boldsymbol{J}$$

$$\boldsymbol{p}_{\text{final}} - \boldsymbol{p}_{\text{initial}} = \boldsymbol{J}$$

Bat-Ball Collisions

From R. Adair, *The Physics of Baseball*

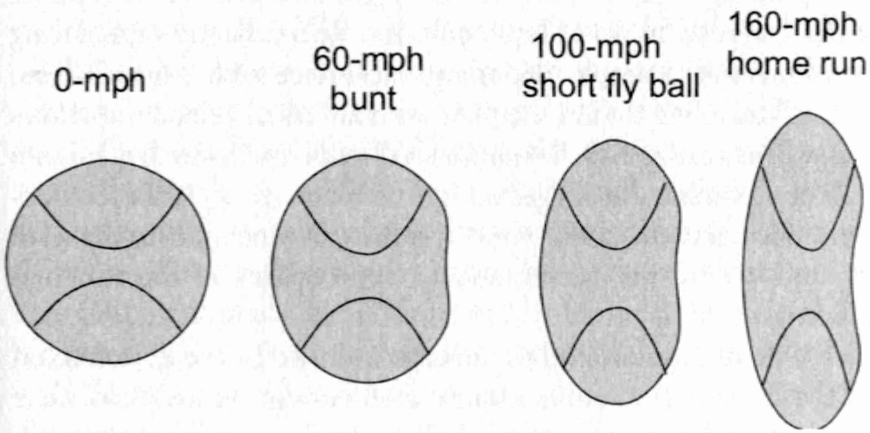


FIGURE 5.5: *Approximate cross sections of balls at the maximum compression point during the bat-ball impact for several impact velocities.*

Source: R. Adair, *The Physics of Baseball*

$$J = \int F dt$$

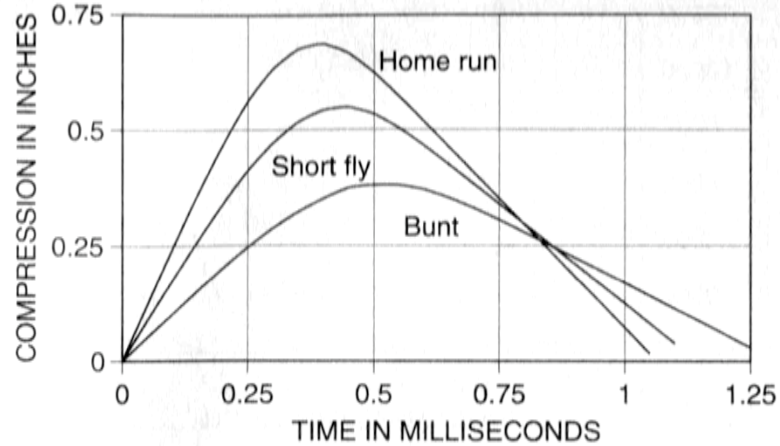
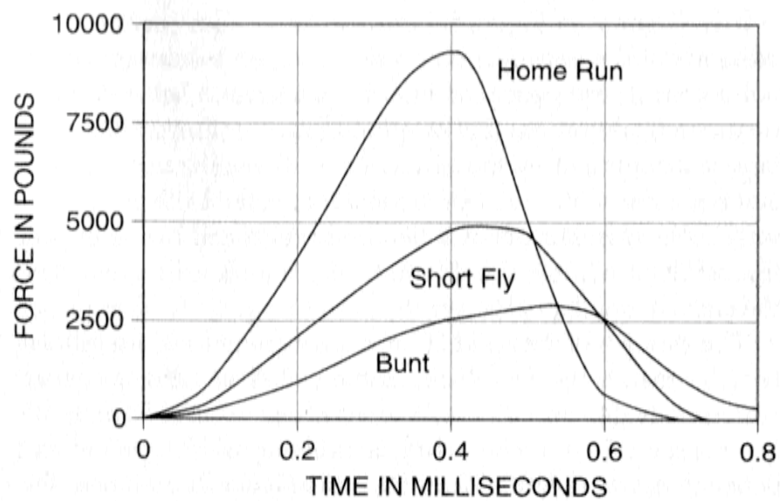


FIGURE 5.4: *The top figure shows the variation in time of ball compression in a ball-bat impact. The lower figure shows the variation in time of the force between the ball and bat. The compressions are distances from the compression face to the center of mass of the ball and thus correspond roughly to changes in the radius of the ball. The bottom figure shows the variation of the bat-ball force as a function of time during the collision.*

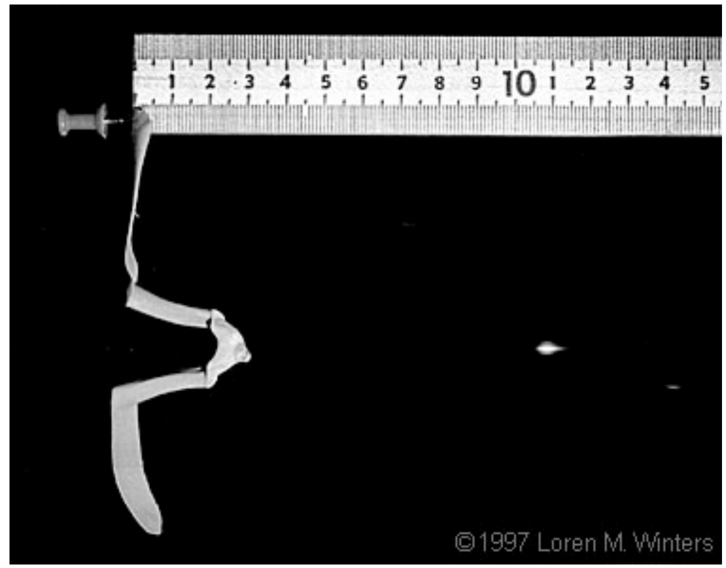
Source: R. Adair, *The Physics of Baseball*



Source: R. Adair, *The Physics of Baseball*

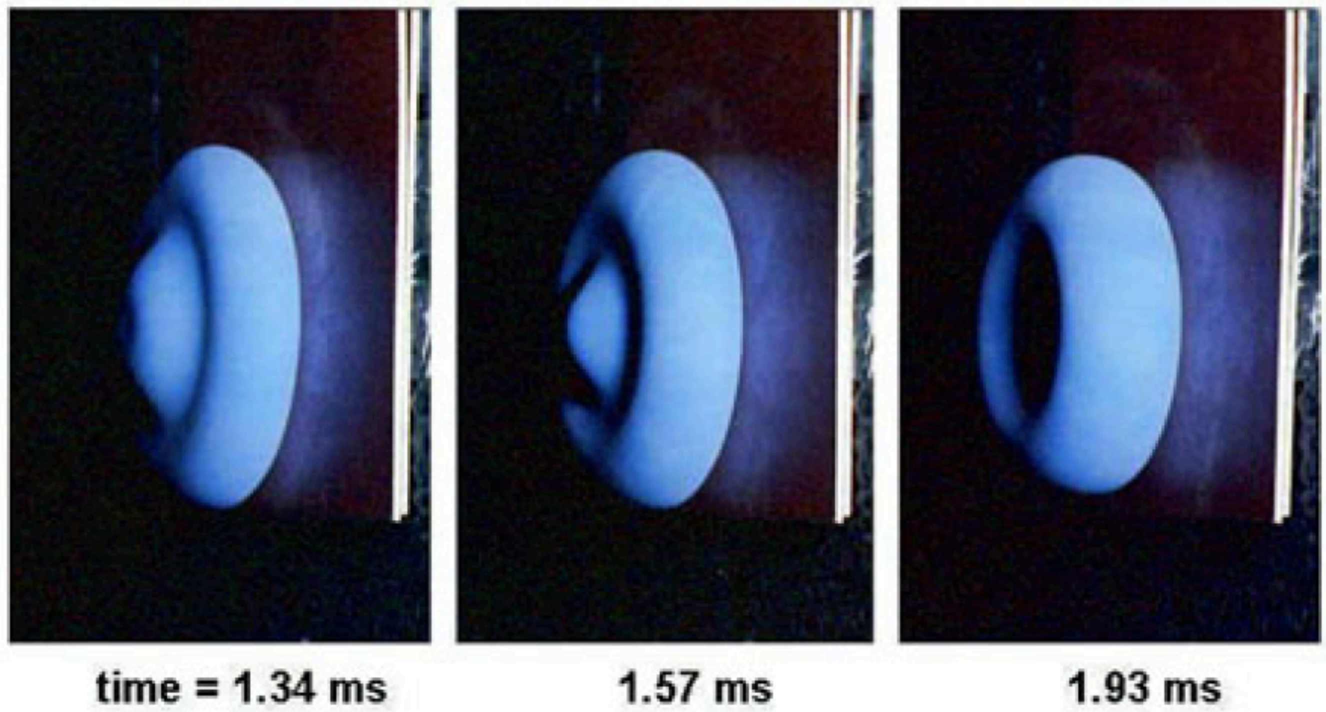
Source: Amoz Eckerson

http://www.hiviz.com/GALLERY/eckerson/impacts/amoz02.html



Source: Loren M. Winters

http://www.hiviz.com/PROJECTS/inertia/punch.htm



Source: Eric Deren and Sean McGrew

http://courses.ncssm.edu/hsi/pacsci/student_photos.html

Colliding bodies: Conservation of linear momentum

In a collision of two objects, the impulsive encounter changes the momentum of both members. But the pair of impulses (AonB and BonA) form a Newton's third law pair, hence

***the impulse experienced by one is equal in magnitude and opposite in direction to the impulse experienced by the other*.**

This leads to the key concept of ***momentum conservation*** *in collisions.*

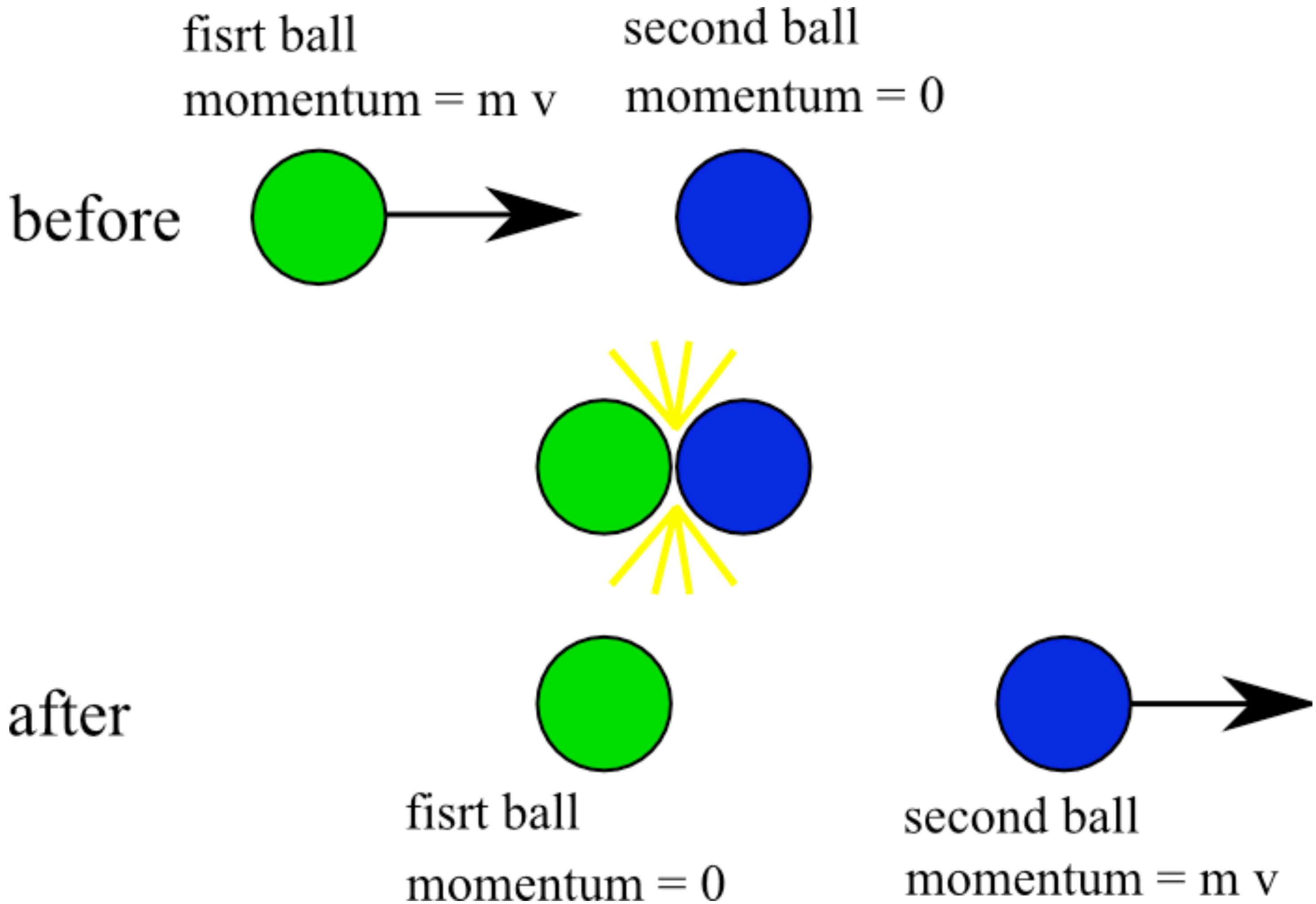
When no net force acts on a pair of colliding bodies, then

the total momentum of the pair is conserved

$$\boldsymbol{P}_{\mathrm{f}} = \boldsymbol{P}_{\mathrm{i}}$$

$$(m_1 \boldsymbol{v}_1 + m_2 \boldsymbol{v}_2)_{\mathrm{f}} = (m_1 \boldsymbol{v}_1 + m_2 \boldsymbol{v}_2)_{\mathrm{i}}$$

A head-on collision of equal mass objects, one initially at rest.



Suppose a tennis ball initially moving horizontally with velocity $\boldsymbol{v}_{\mathrm{i}}$ is struck by a second ball that ends up exactly reversing the first ball's direction ($\boldsymbol{v}_{1\mathrm{f}} = -\boldsymbol{v}_{1\mathrm{i}}$). Which of the following statement about the encounter is true?

1) **The momentum of the two-ball system is constant and the second ball does zero work on the first.**
2) **The momentum of the two-ball system is constant and the second ball does non-zero work on the first.**
3) **The momentum of the two-ball system is not constant and the second ball does zero work on the first.**
4) **The momentum of the two-ball system is not constant and the second ball does non-zero work on the first.**

You are in a boat resting on a lake on a perfectly calm day. You fall asleep and lose your oars overboard. Spying two large but unequal size rocks lying in your boat (for ballast? for hitting carp?), you get the brilliant idea of throwing the rocks from the boat away from shore so that your boat will recoil and drift into port. If you throw the rocks with some fixed velocity v_{rel} (relative to you), what scheme will end up giving you and your boat the fastest trip back to shore?

1. throw both rocks simultaneously.
2. throw the lighter, then the heavier.
3. throw the heavier, then the lighter.
4. it doesn't matter how you throw them.