Announcements 6 Apr 09

- Exam 2
  - Tomorrow from 7 to 9 pm
  - TONIGHT:
    - Help session from 5 to 7 pm in HAS 20
    - SI session from 7:15 to 8:30 pm (as usual)
- Homework #9
  - Will be due on Friday

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Chapter 9 Momentum

Topics:

- Interactions from the viewpoint of impulse and momentum
- Isolated systems
- Conservation of momentum
- Applications to inelastic collisions, explosions and recoil

Sample question:

Male rams butt heads at high speeds in a ritual to assert their dominance. How can the force of this collision be minimized so as to avoid damage to their brains?

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Impulse

- Consider a collision between two objects, e.g.,
  - bat and baseball
  - racket and tennis ball
- Ball is compressed during the short duration of the contact (1 to 10 ms)

- Other example: soccer ball kick

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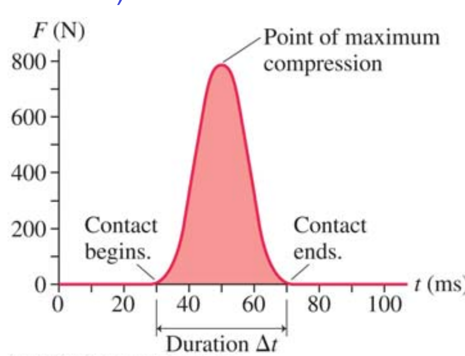
Impulse

- The foot exerts a force on the ball during a well-defined duration Δt (time extent of the contact)
- A greater force and/or longer duration will have a greater effect ➔ greater ***impulse***



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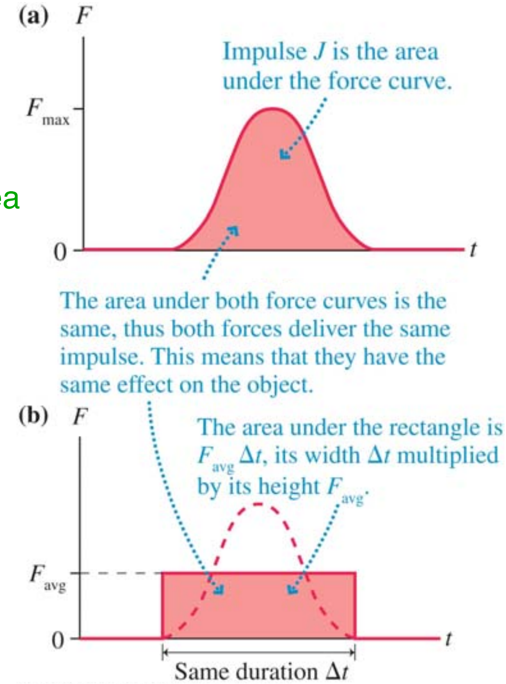
Impulse



Define **impulse *J*** as the area under the force curve

$$J = F_{avg}\,\Delta t$$

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Impulse-Momentum Theorem

What is the connection between impulse and motion?

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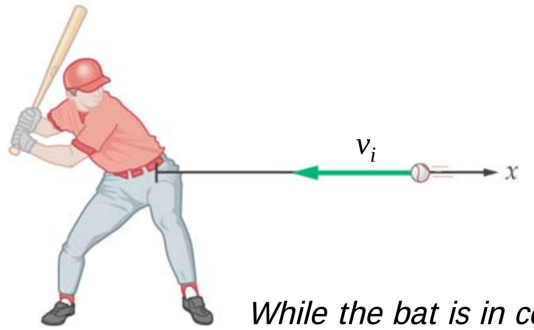
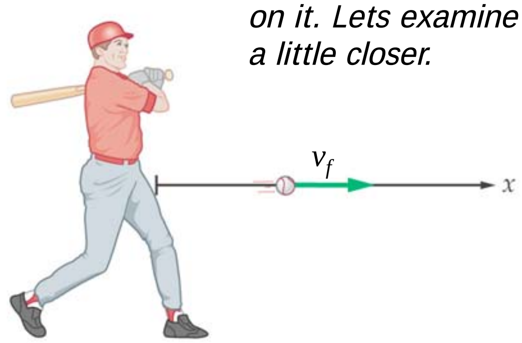
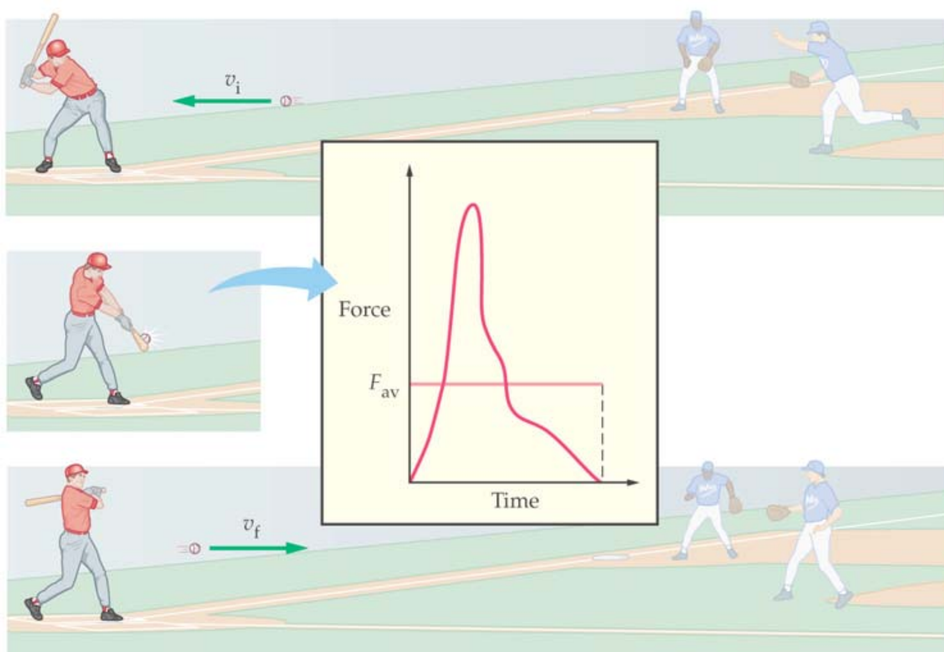


While the bat is in contact with the ball it exerts a force on it. Lets examine this force a little closer.





Impulse-Momentum Theorem

What is the connection between impulse and motion?

• From Newton's 2nd Law, we have

$$\vec{a}_{avg} = \frac{\vec{F}_{avg}}{m}$$

• Recall that acceleration is a change in velocity

$$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

• Combining these, we obtain

$$\frac{\vec{F}_{avg}}{m} = \vec{a}_{avg} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

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

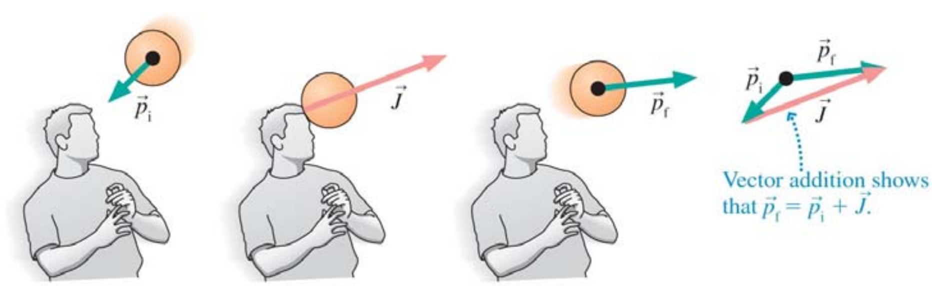
$$\Rightarrow \boxed{\vec{J} = \vec{p}_f - \vec{p}_i = \Delta\vec{p}}$$

Momentum *is defined as*

$$\vec{p} = m\vec{v}$$

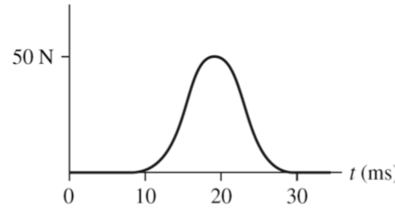
Effect of impulse on motion

$$\boxed{\vec{J} = \vec{p}_f - \vec{p}_i = \Delta\vec{p}} \qquad \boxed{\vec{p} = m\vec{v}}$$



Impulse problem

A 0.5-kg hockey puck slides to the right at 10 m/s. It is hit with a hockey stick that exerts the force shown. What is its approximate final speed?



1. compute impulse

$$J = F_{avg}\Delta t$$

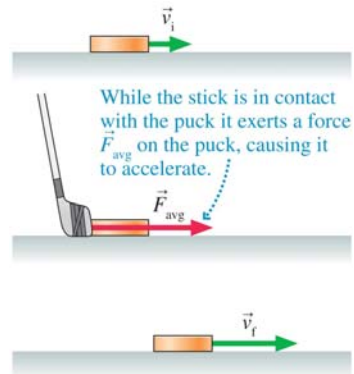
$$J = (25N)(0.020s) = 0.5\ N\cdot s = 0.5\ kg\cdot m/s$$

2. apply impulse-momentum theorem

$$\vec{J} = \vec{p}_f - \vec{p}_i = m(\vec{v}_f - \vec{v}_i)$$

$$\frac{\vec{J}}{m} = \vec{v}_f - \vec{v}_i \quad \Rightarrow \frac{\vec{J}}{m} + \vec{v}_i = \vec{v}_f$$

$$\frac{0.5\ \text{kg}\cdot\text{m/s}}{0.5\ \text{kg}} + 10\ \text{m/s} = \left(v_f\right)_x = 11\ \text{m/s}$$



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Impulse DEMOS

- Table setting
- Pen and hoop

Momentum change is very small because force is applied for a very short time

- Pendulum hit by bat vs. finger push

$$\boxed{\vec{F}_{avg}\Delta t = \Delta\vec{p}}$$

- Egg toss

Force on the egg is minimized by stretching the length of time over which momentum drops to zero

$$\vec{F}_{avg}\Delta t = \Delta\vec{p} \Rightarrow \vec{F}_{avg} = \Delta\vec{p}/\Delta t$$

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Impulse question

PRS

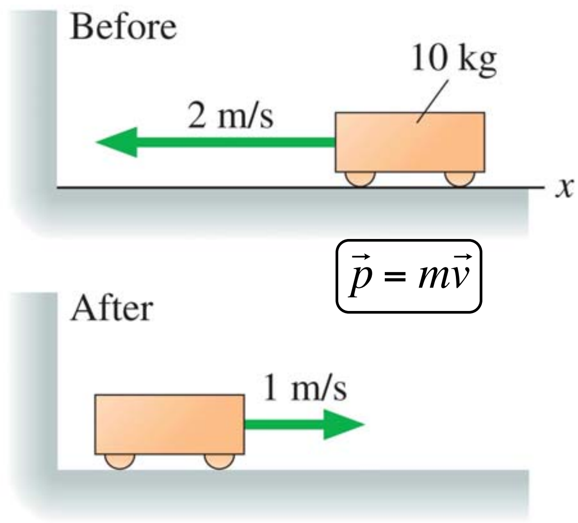
The cart's change of momentum is

A. -30 kg m/s

B. -10 kg m/s

C. 10 kg m/s

D. 30 kg m/s



Momentum Recap

$$\vec{p} = m\vec{v}$$

This equation expresses the momentum of a single particle or a collection of them.

For more than one particle the total momentum is the sum of the momentum of individual particles.

$$\vec{p} = \vec{p}_1 + \vec{p}_2 + \vec{p}_3 + \ldots = \sum_i \vec{p}_i$$

The SI units of momentum: kg m/s

Conservation of Momentum

Consider a collision btw two balls

Impulse-momentum thm:

$\Delta p_{1x} = J_{1x}$ and $\Delta p_{2x} = J_{2x}$

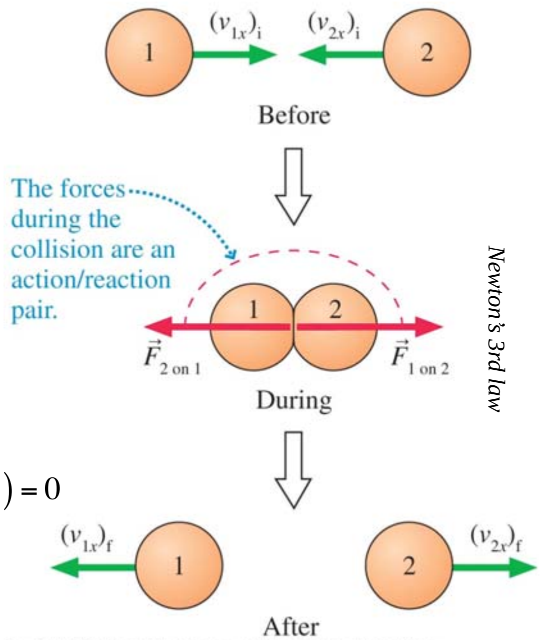
Since $(F_{2on1})_x = -(F_{1on2})_x$, we have $J_{1x} = - J_{2x}$, and thus

$\Delta p_{1x} = -\Delta p_{2x}$

i.e., $\Delta p_{1x} + \Delta p_{2x} = \Delta\left(p_{1x} + p_{2x}\right) = 0$

The sum of the momenta does not change

$\left(p_{1x}\right)_f + \left(p_{2x}\right)_f = \left(p_{1x}\right)_i + \left(p_{2x}\right)_i$



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Conservation of Momentum

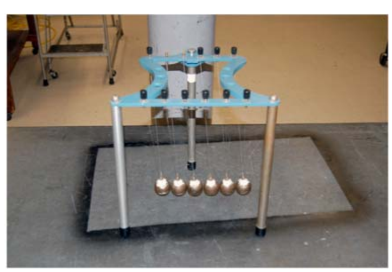
The total momentum before the collision is equal to the total momentum after the collision

This can be generalized to any *isolated* system consisting of any number of particles

➔ Law of momentum conservation

One of the most general and important Laws of Nature

DEMOS:
- pull-apart carts
- rocket propulsion
- Newton's cradle



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