Physics Softball Chalk Talk: How To Hit It Hard!

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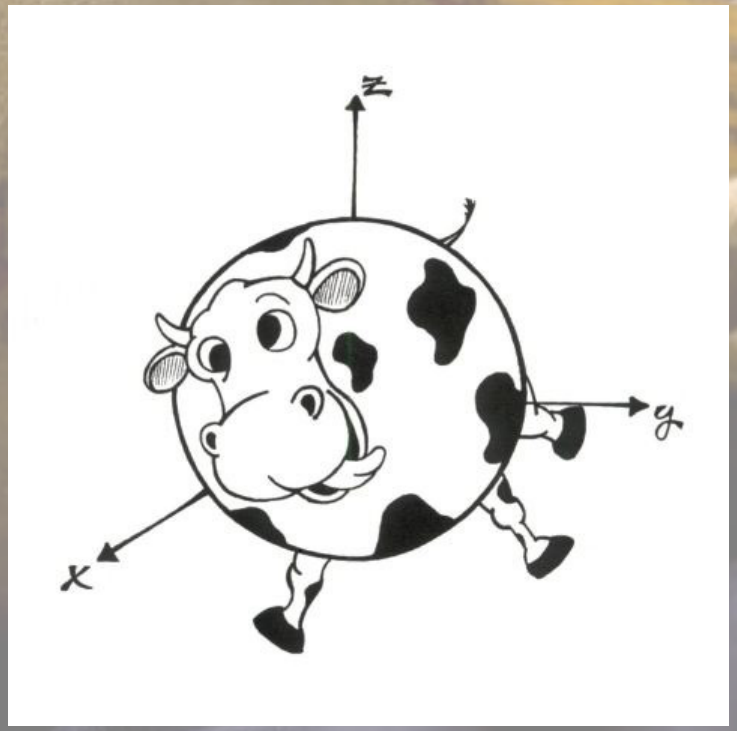
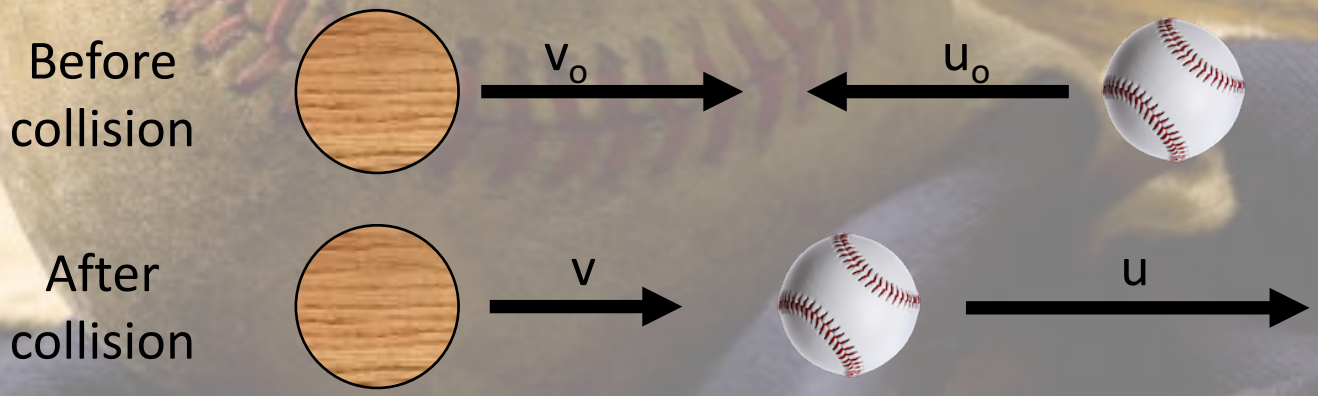
How do you get cows to produce more milk?

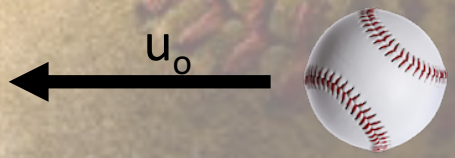


Consider the bat and ball as point particles…

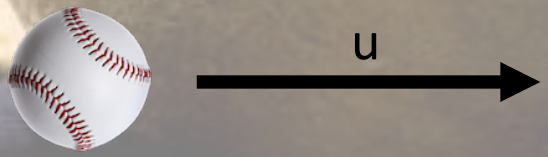


Is Linear Momentum Conserved?

Does the force the batter exerts on the bat during the collision make a difference?



$$\vec{F} = \frac{d\vec{p}}{dt} \qquad F = \frac{m(u + u_o)}{\Delta t}$$

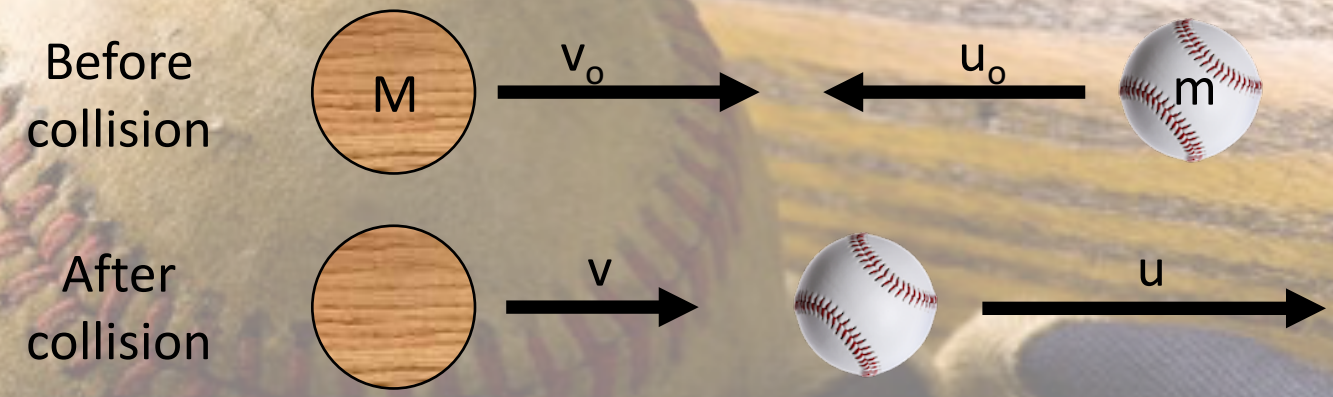


In Major League Baseball:
m = 5.125oz u = u_o = 90mph Δt = 1 ms

After an epic struggle with English units…
F = 3000lbs!

Just in case you don't think you can hit it hard without exerting any force during the collision…

Consider the bat and ball as point particles that conserve linear momentum

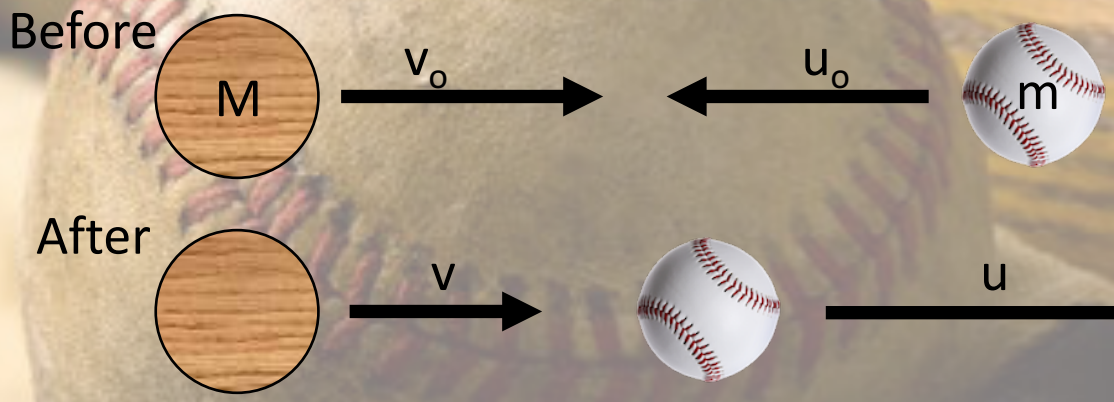


$$Mv_o - mu_o = Mv + mu$$

Solving for the outgoing speed of the ball…

$$u = \frac{1}{\mu}(v_0 - v) - u_o \quad \text{where} \quad \mu = \frac{m}{M}$$

How do we eliminate the speed of the bat after collision?



$$u = \frac{1}{\mu}(v_0 - v) - u_o$$

Coefficient of Restitution $\mathbf{e} = \frac{u-v}{v_0+u_o}$

Energy is Definitely Not Conserved

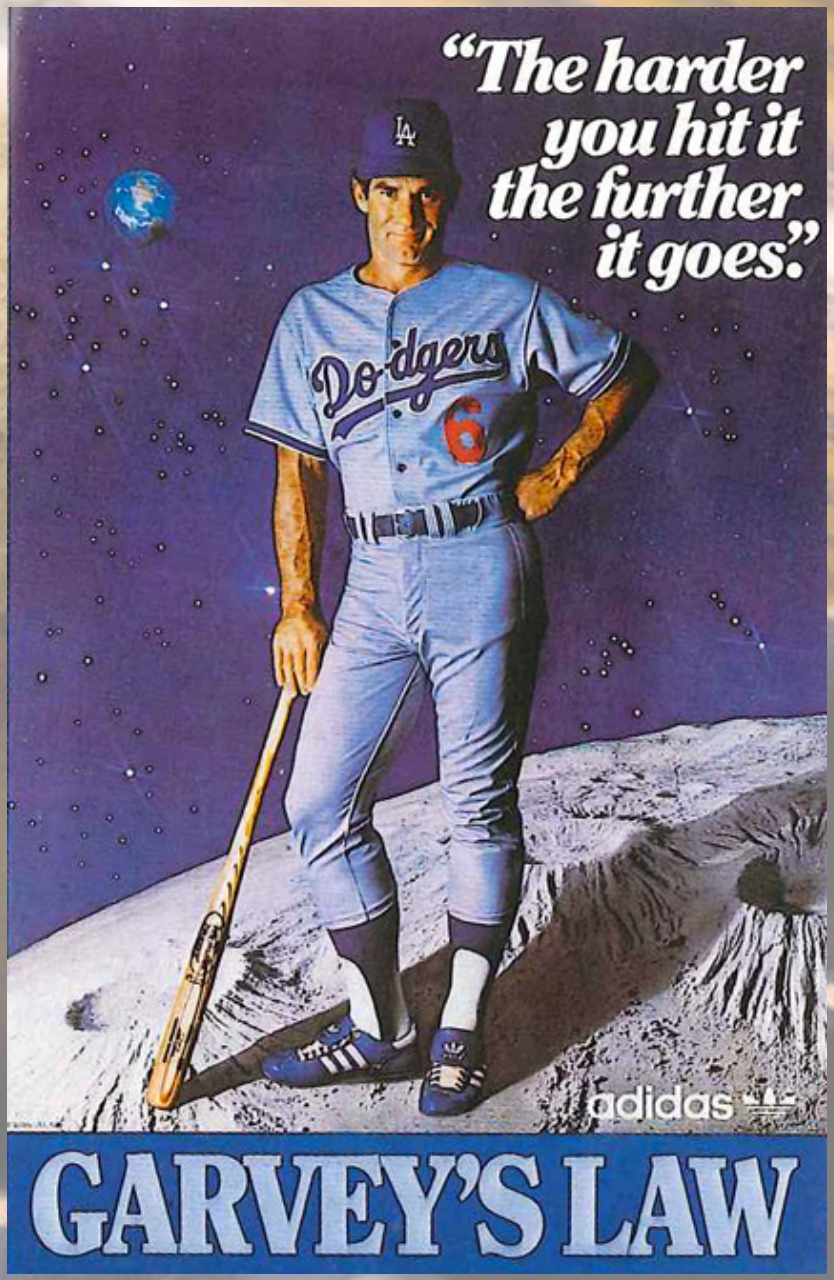
How do we eliminate the speed of the bat after collision?

Doing the Math…

$$\mathbf{e} = \frac{u - v}{v_0 + u_o}$$

$$u = \left(\frac{1 + e}{1 + \mu}\right) v_o + \left(\frac{e - \mu}{1 + \mu}\right) u_o$$

$$u = \frac{1}{\mu}(v_0 - v) - u_o$$


"The harder you hit it the further it goes."
Dodgers
6
adidas
GARVEY'S LAW

That's as far as we can go with point particles.

$$u = \left(\frac{1+e}{1+\mu}\right)v_o + \left(\frac{e-\mu}{1+\mu}\right)u_o$$

We have to give up on the spherical cow!

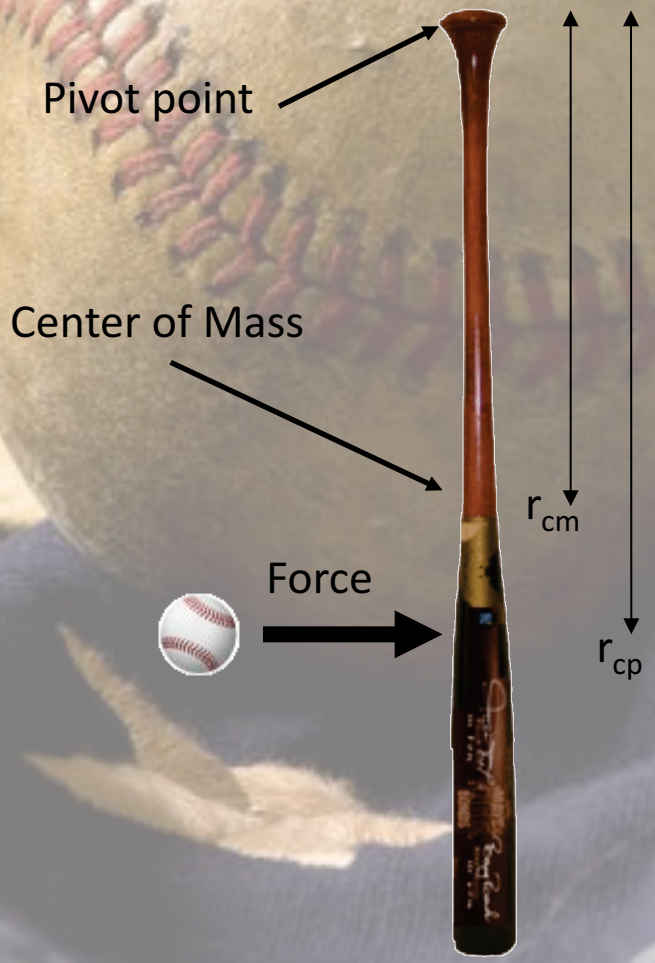
A real cow and a real bat are extended objects.

Where Should the Bat Strike the Ball?

One answer is the Center of Percussion

The spot were the collision causes no reaction force back on your hands.

That means the bat is in pure rotation about the end.



Second Law for Rotation

$$\sum \tau = I\alpha$$

$$r_{cp}F = I\alpha$$

Pure Rotation

$$r_{cp}F = I\frac{a}{r_{cm}}$$

Second Law

$$r_{cp}ma = I\frac{a}{r_{cm}}$$

Center of Percussion

$$r_{cp} = \frac{I}{mr_{cm}}$$

Where Should the Bat Strike the Ball?

Find the COP experimentally.

Where Should the Bat Strike the Ball?

Another answer is at a vibrational node.

Where Should the Bat Strike the Ball?

Does a bat really vibrate?

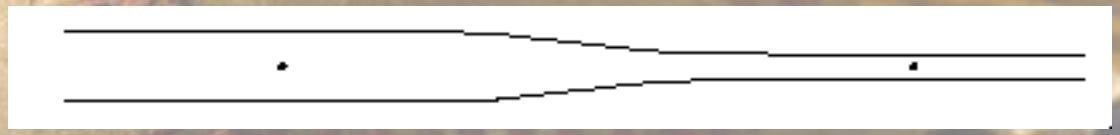
Where Should the Bat Strike the Ball?

Does this happen in a real game?

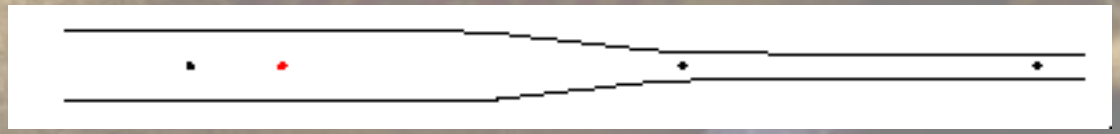
Where Should the Bat Strike the Ball?

The vibrational nodes (VN)

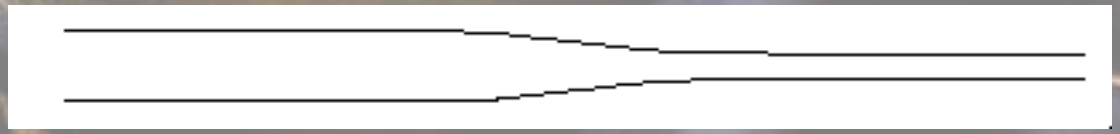
The standing waves on a baseball bat



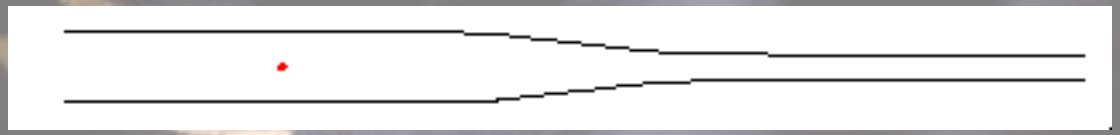
fundamental



1st overtone



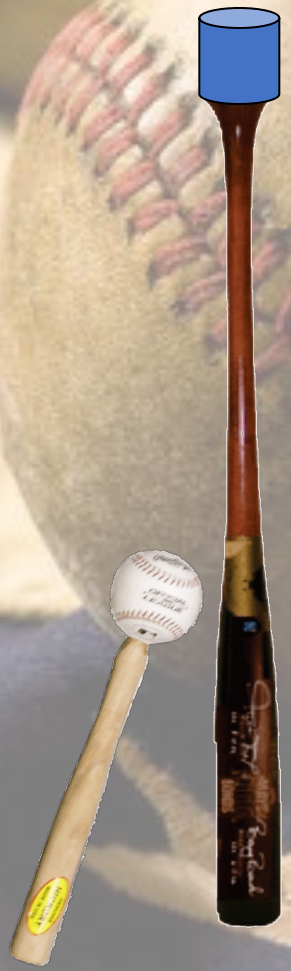
2nd overtone



3rd overtone

Where Should the Bat Strike the Ball?

The vibrational nodes (VN)

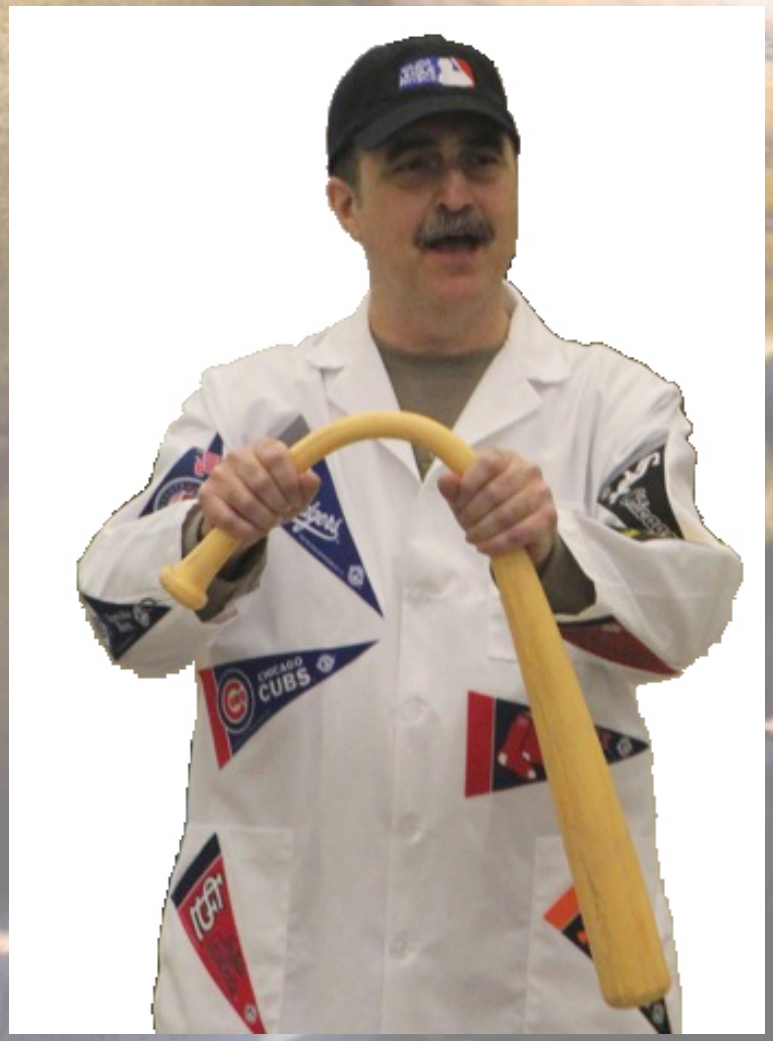


If you wrap a paper megaphone around the top of the bat you can hear the vibrations.

The place where the sounds is minimum is the node of the fundamental.

Where Should the Bat Strike the Ball?

The vibrational nodes (VN)



Where Should the Bat Strike the Ball?

The vibrational nodes (VN)

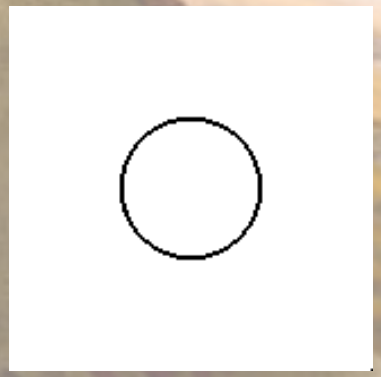
Where Should the Bat Strike the Ball?

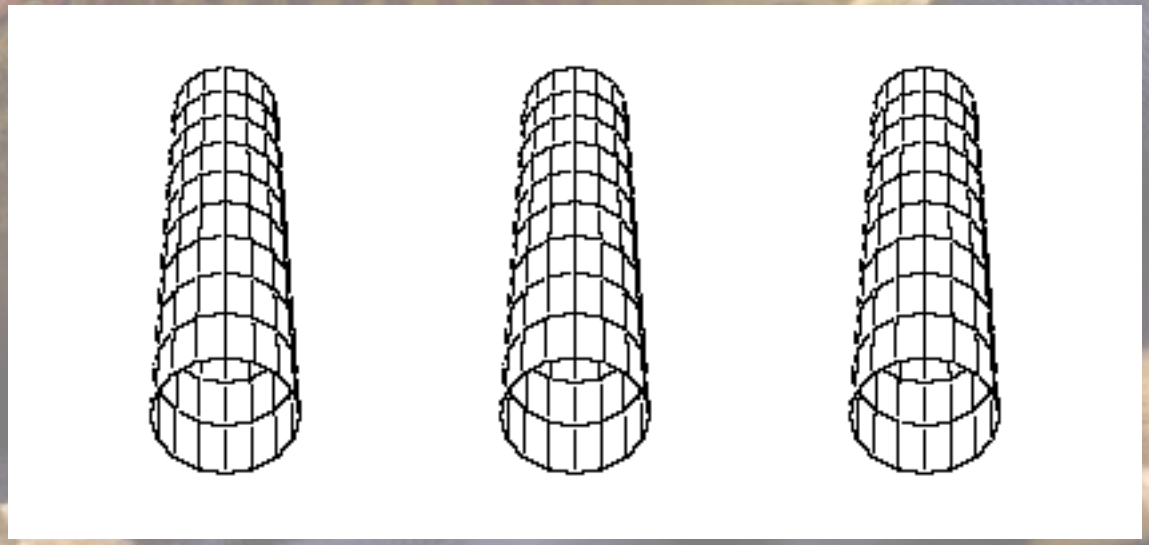
Why are aluminum bats different than wooden bats?

The internal vibrations of aluminum bats can be engineered.

Where Should the Bat Strike the Ball?

The hoop modes of a hollow bat





fundamental 1st overtone 2nd overtone

Physics Softball Chalk Talk: How To Hit It Hard!

- Linear momentum is conserved in ball-bat collisions
- The coefficient of restitution (COR) is a measure of mechanical energy lost to heat.
- A faster bat and a faster pitch will result in harder hits.
- The center of percussion (CP) will reduce the forces back on your hands.
- The vibrational node (VN) will reduce energy lost to bat vibration.
- The CP and VN are in about the same spot – so hit it there!
- Aluminum bats are a bit more complex, but the same advice still applies.