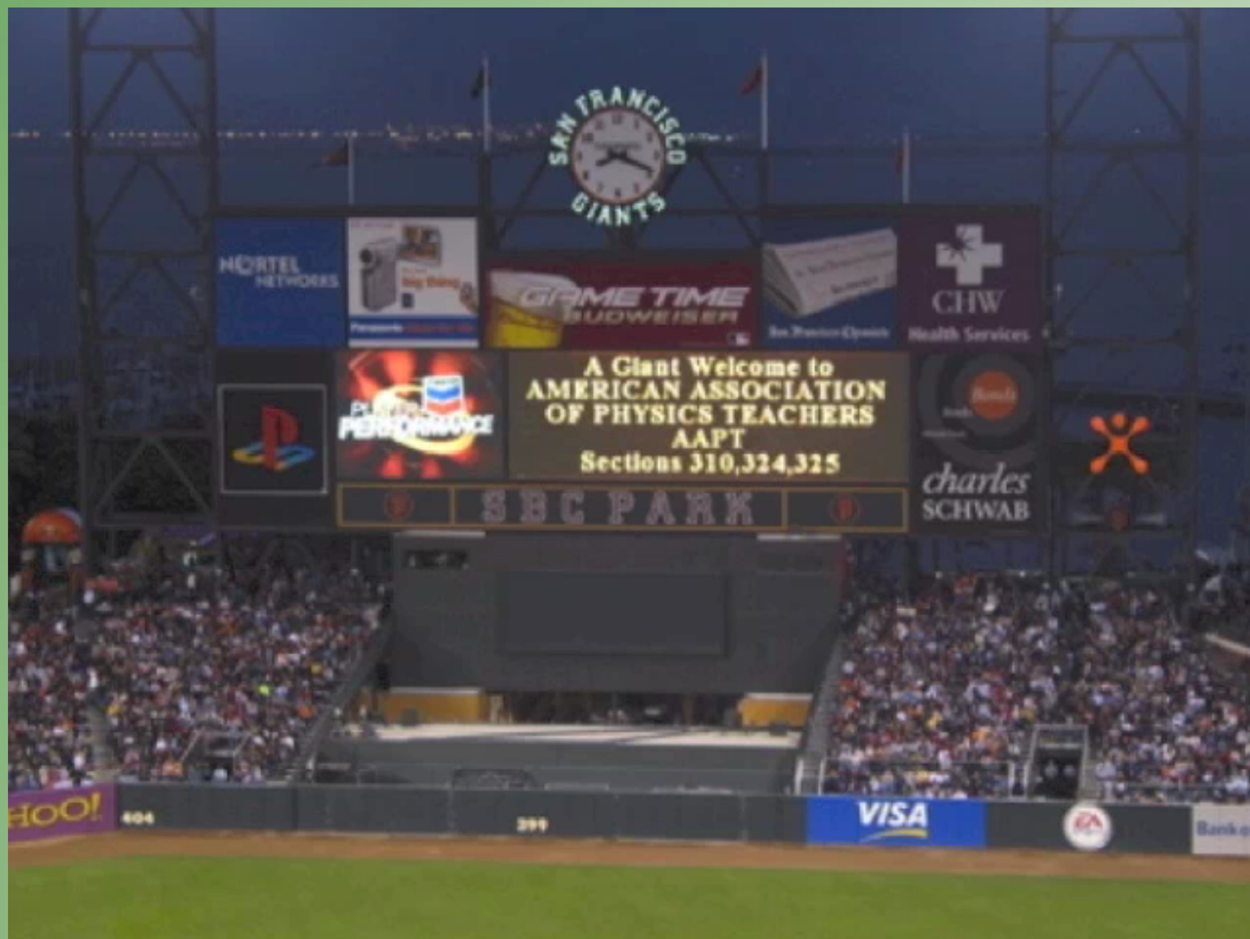
Put Me in Coach!

The Physics of Baseball



Put Me in Coach!

The Physics of Baseball

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Department of Science Education
California State University, Chico

Baseball on Mars

Atwood's Machine!

$$F_{net} = ma$$

$$mg - \frac{mg}{2} = (m + \frac{m}{2})a$$

$$\frac{mg}{2} = \frac{3}{2}ma$$

$$a = \frac{g}{3}$$

Baseball on Mars

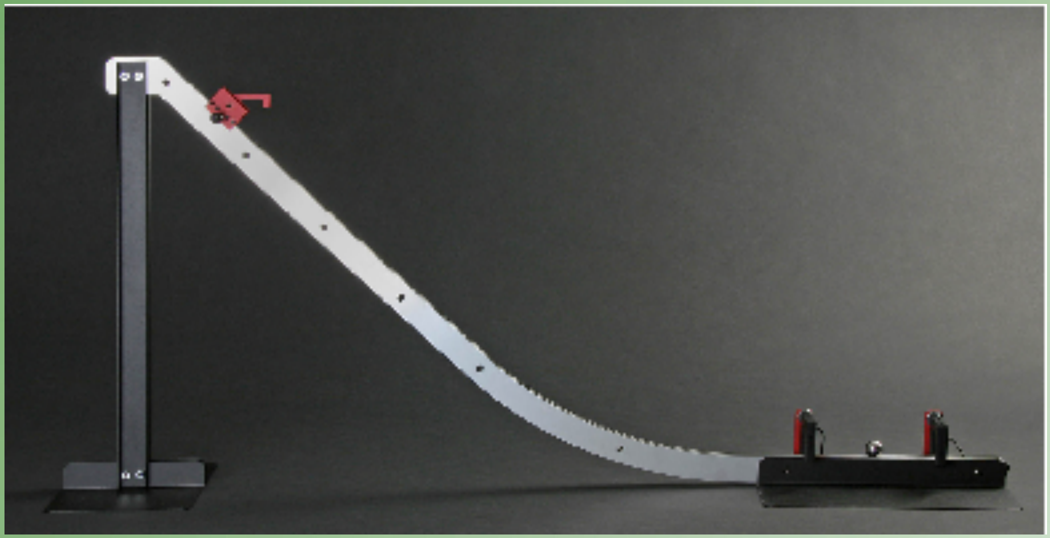
- How would playing baseball be different on Mars?

Baseball on Mars

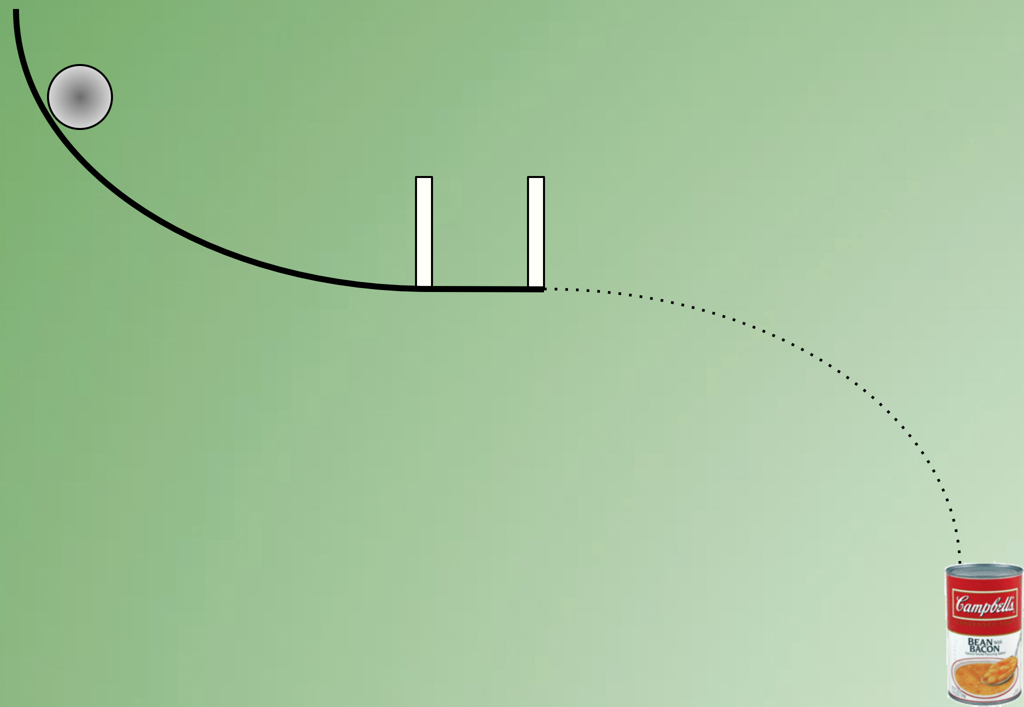
•How would you have to modify the playing field so that the game on Mars is similar to a game played on Earth?

Baseball on Mars

Bull’s Eye Lab



Bull's Eye Lab



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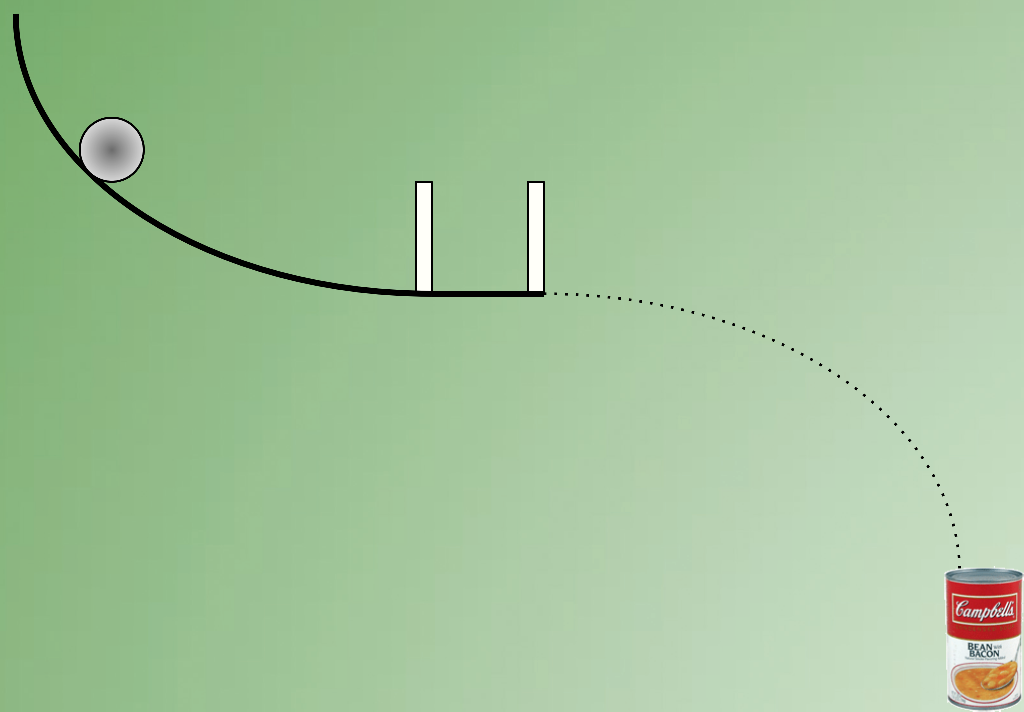

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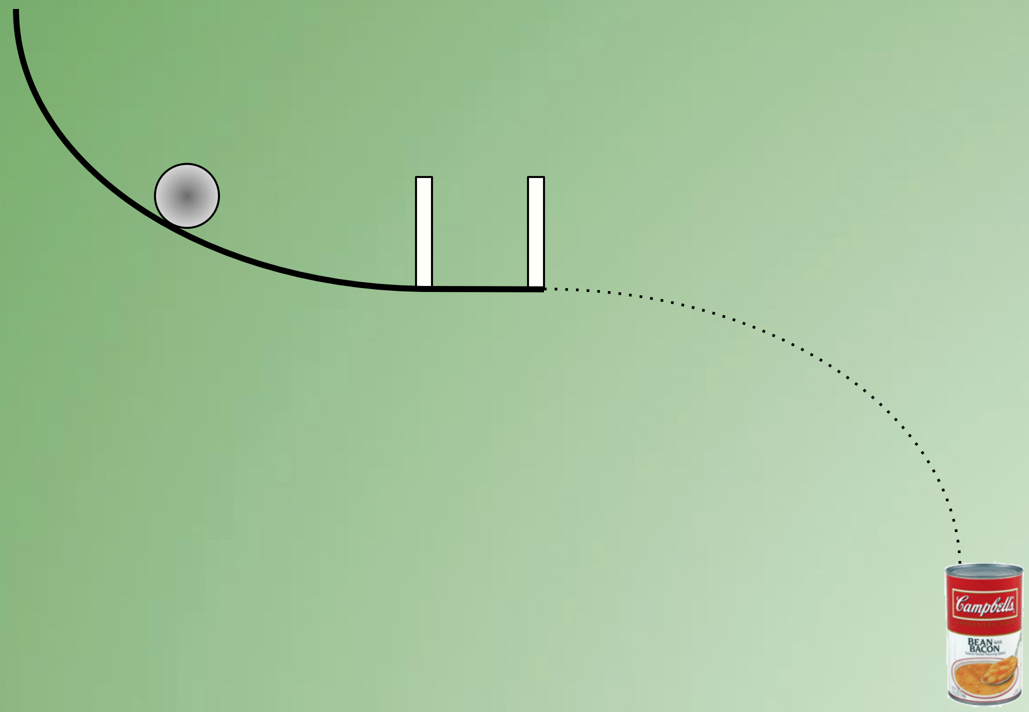

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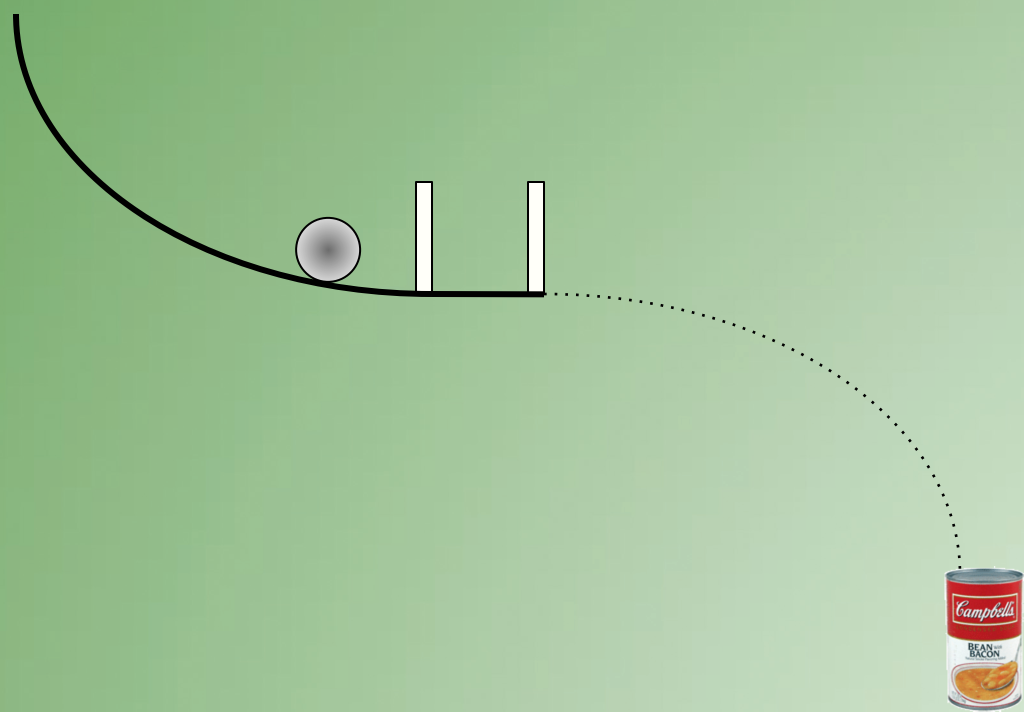

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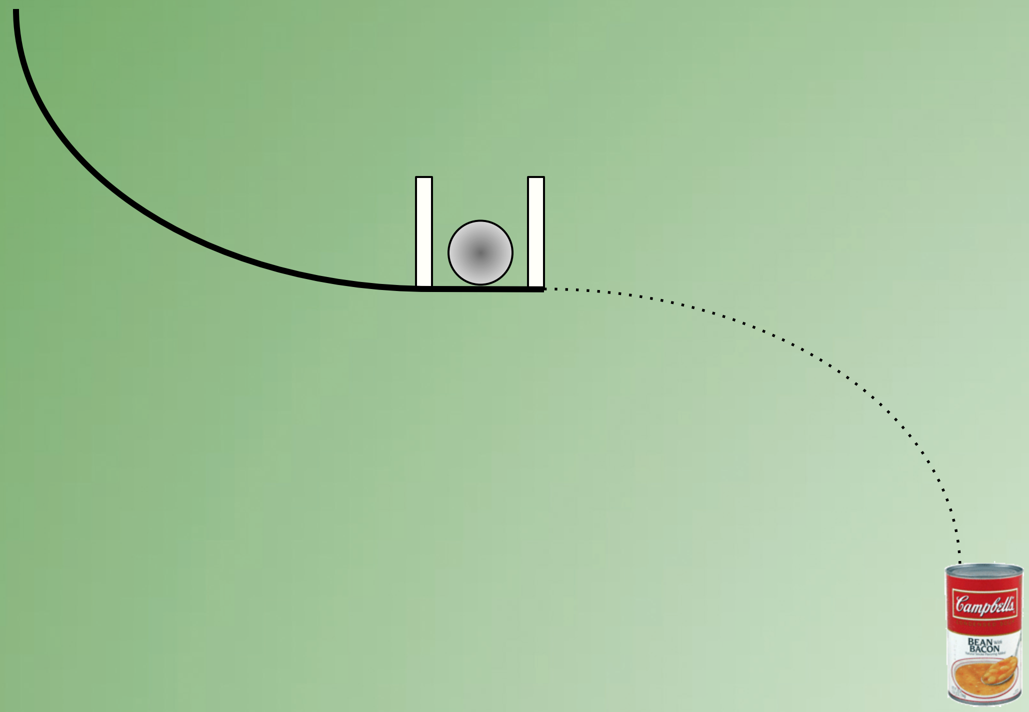

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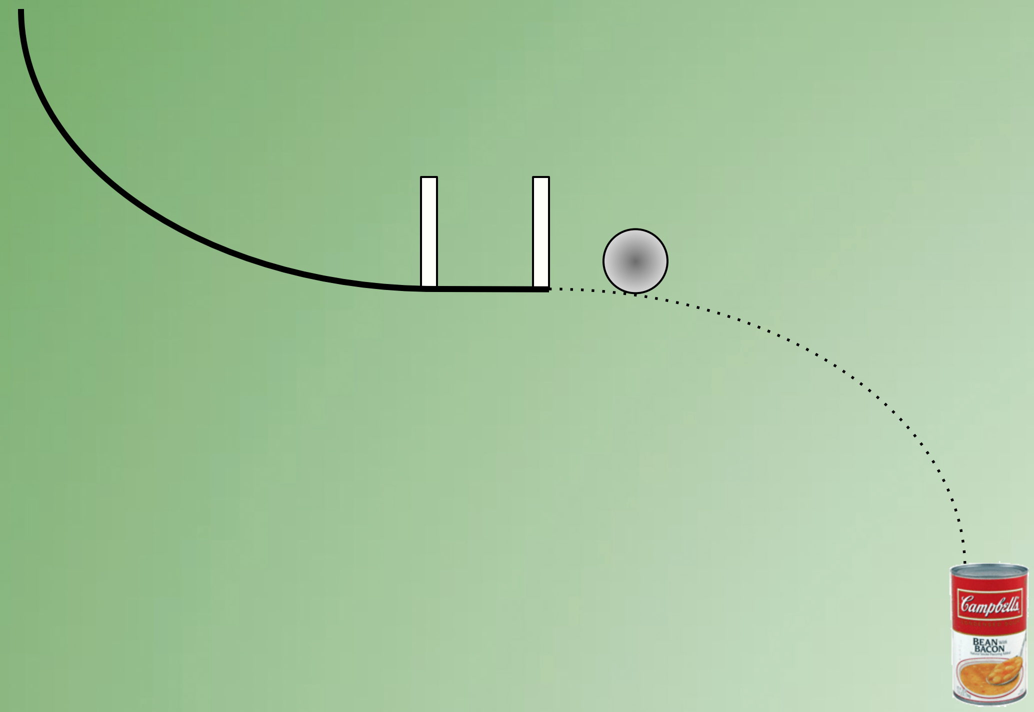

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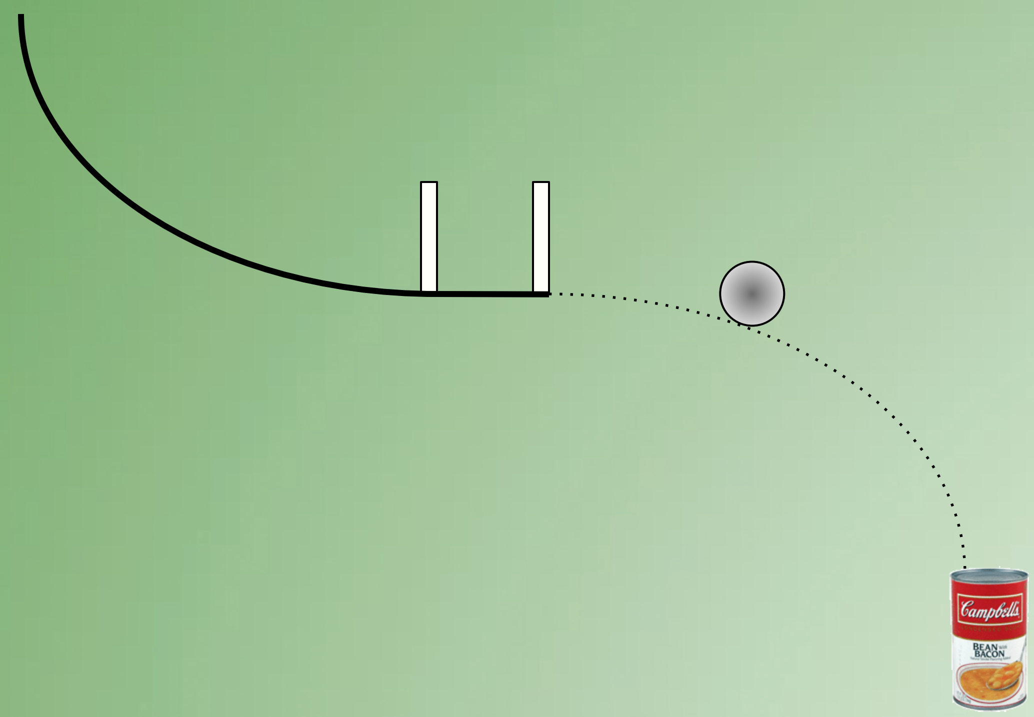

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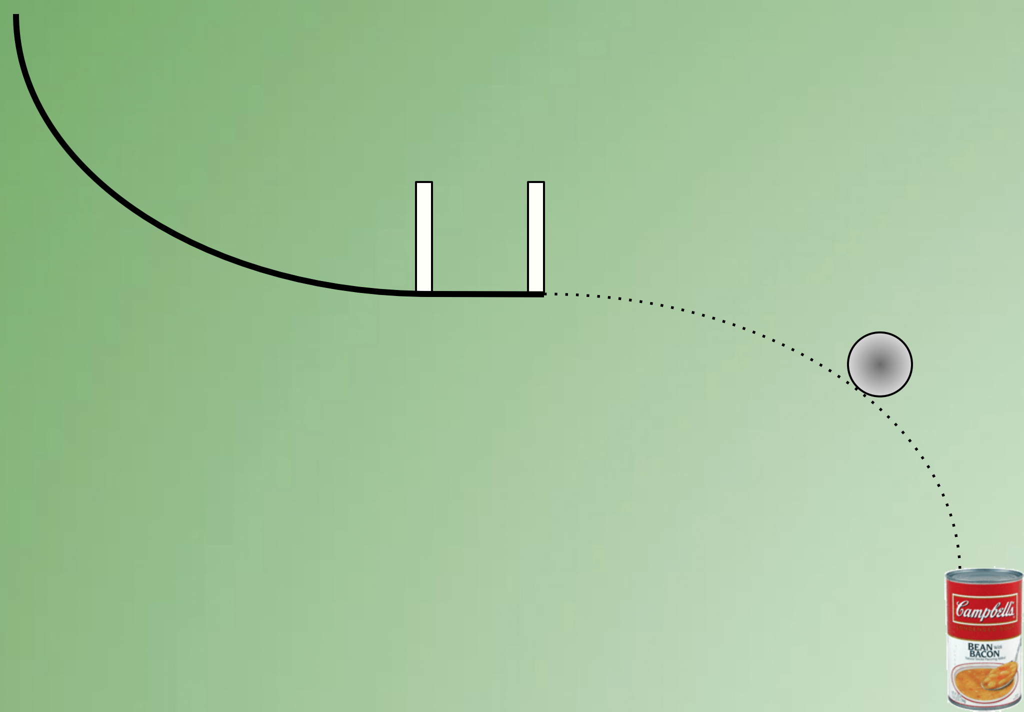

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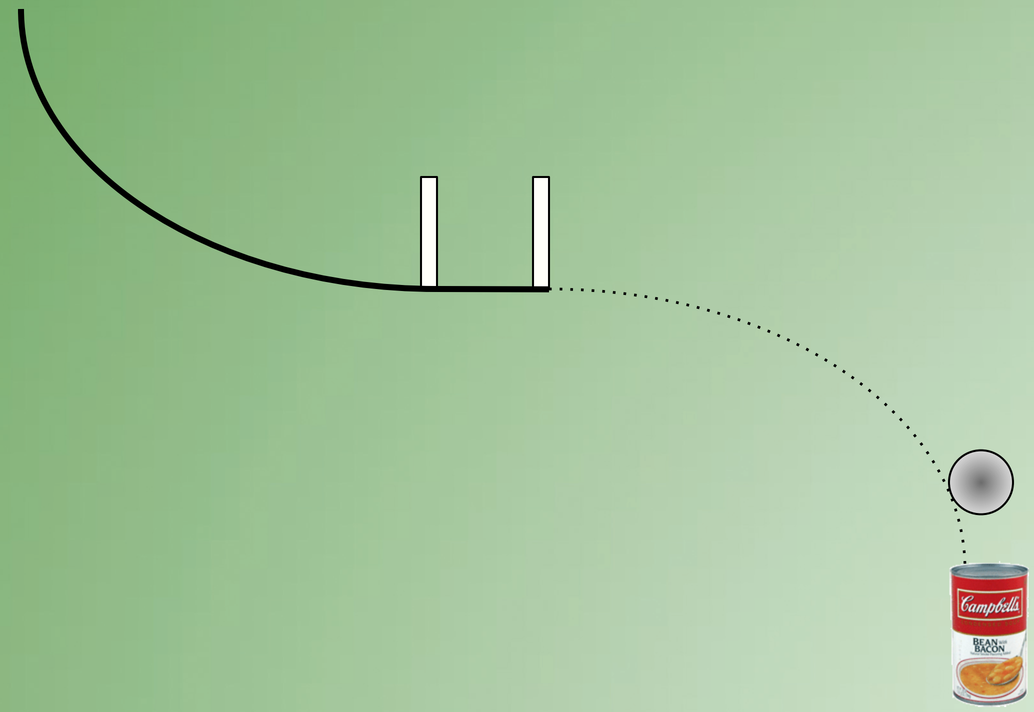

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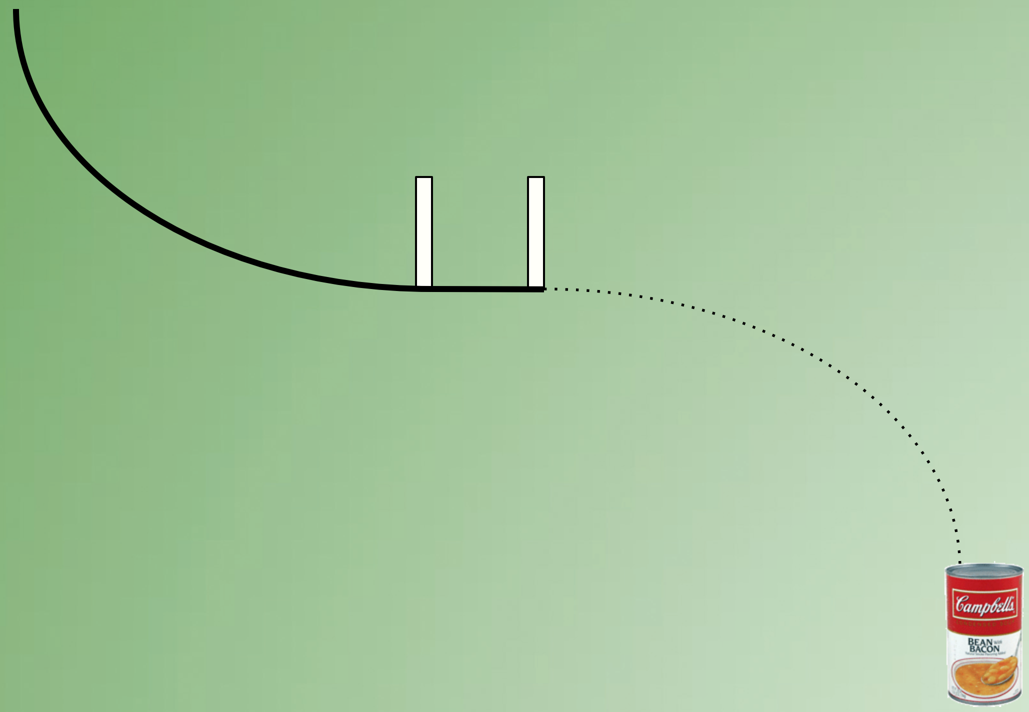

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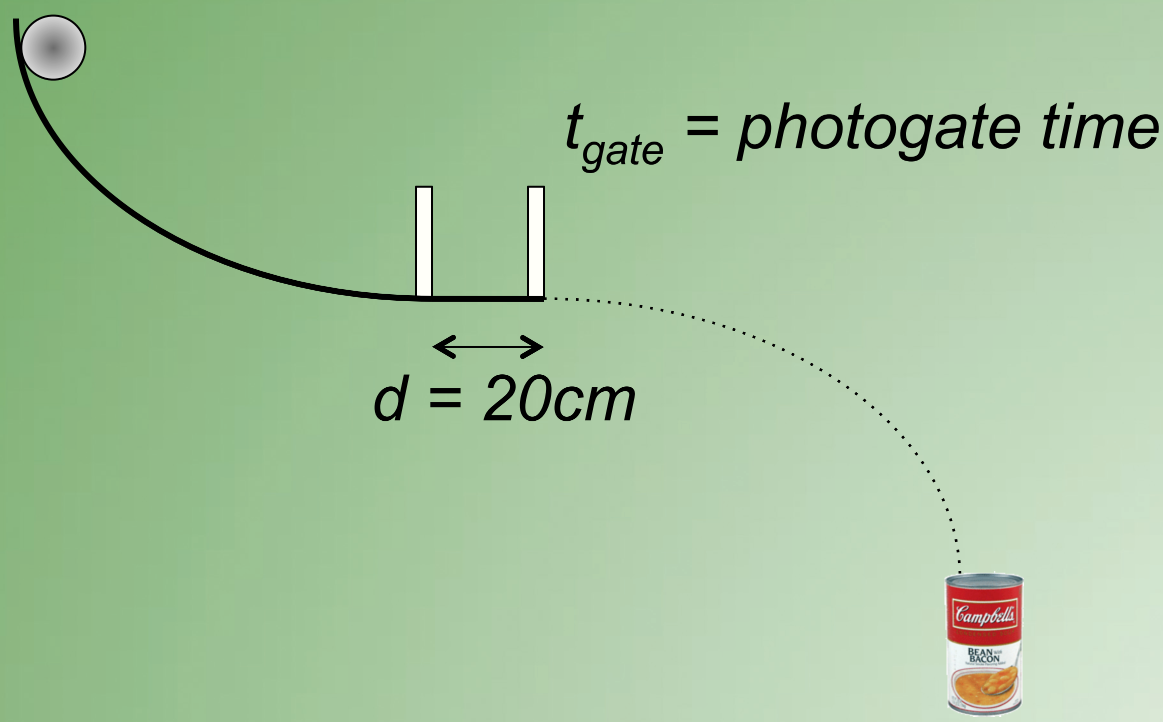

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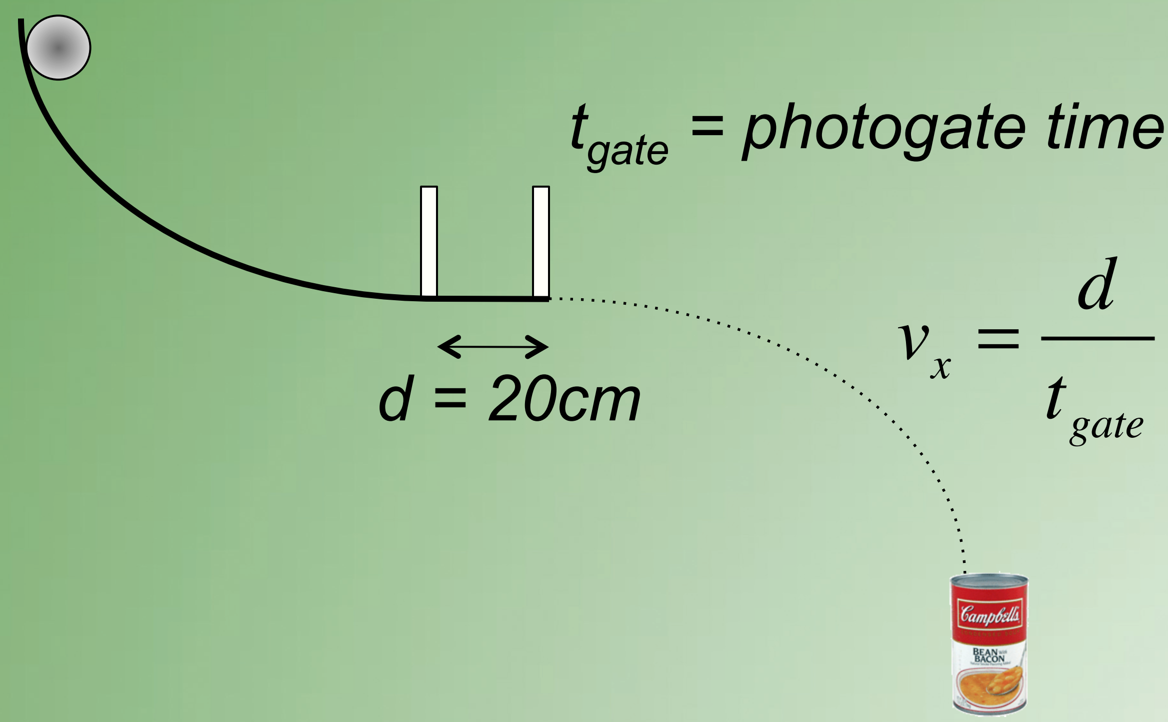

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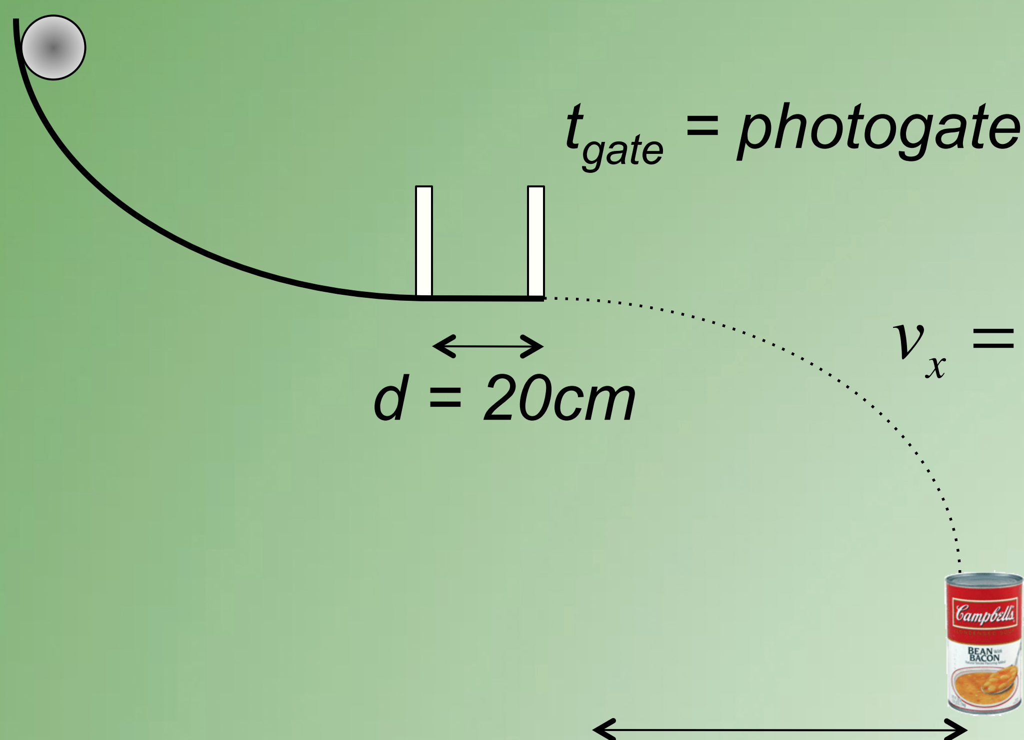


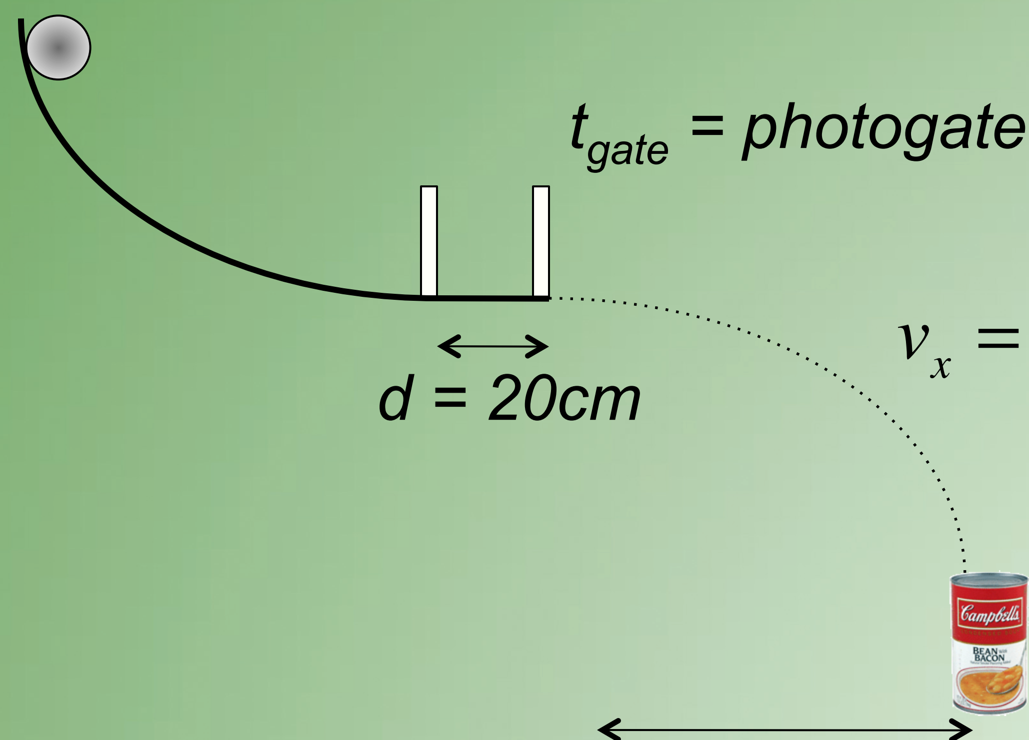
t_{gate} = photogate time

d = 20cm

$$v_x = \frac{d}{t_{gate}}$$

$$d_x = v_x t_{top}$$

Bull's Eye Lab

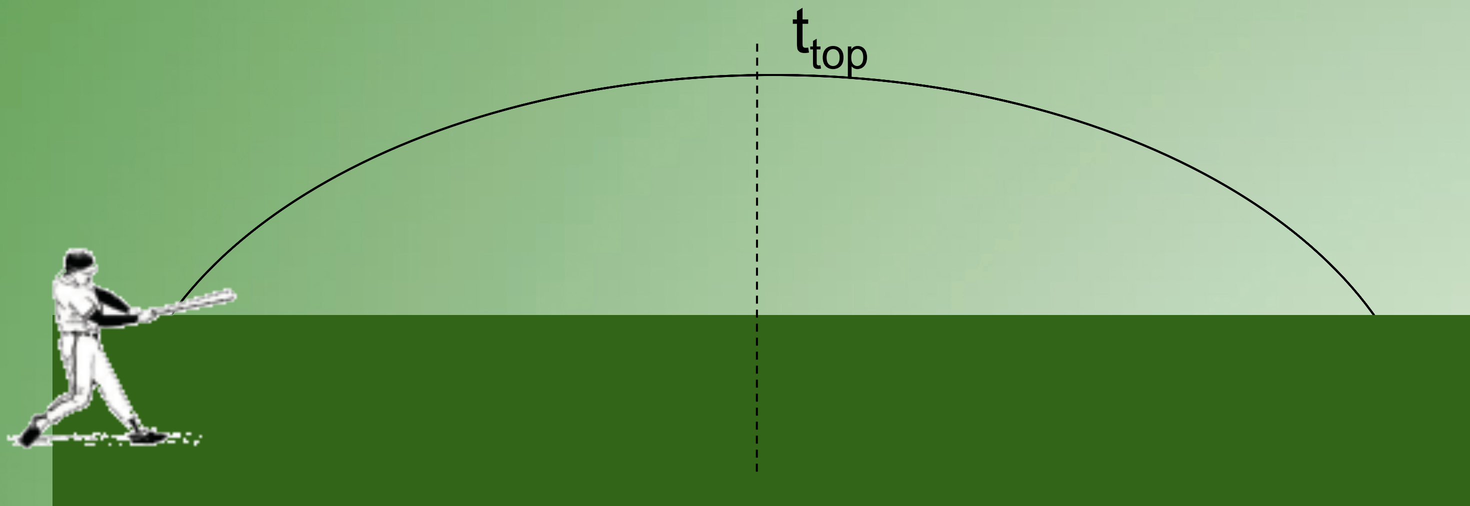


$$v_x = \frac{d}{t_{gate}}$$

$$d_x = v_x t_{top}$$

$$t_{top} = \sqrt{\frac{2h}{g}}$$

Bull's Eye Lab



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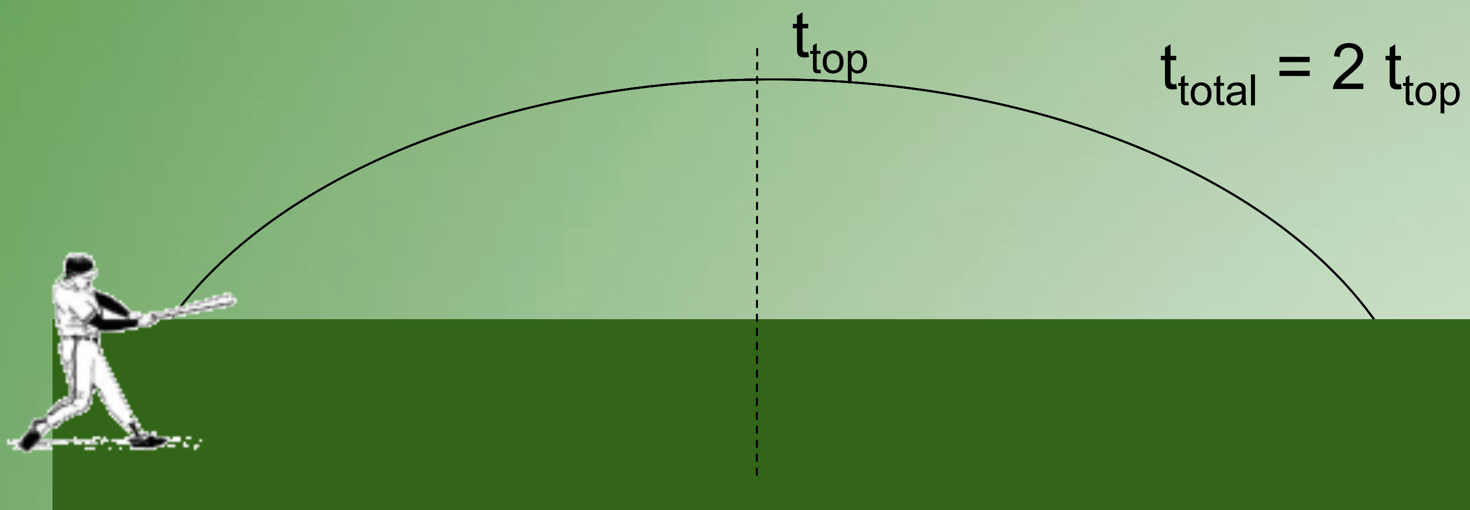

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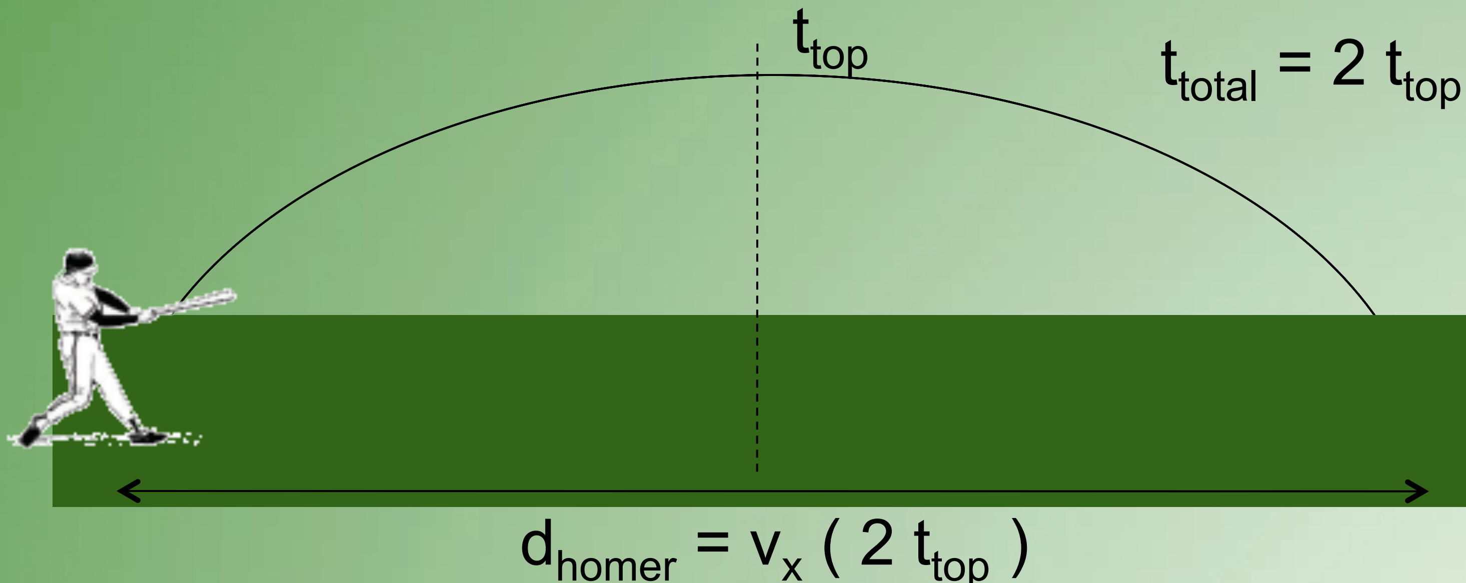
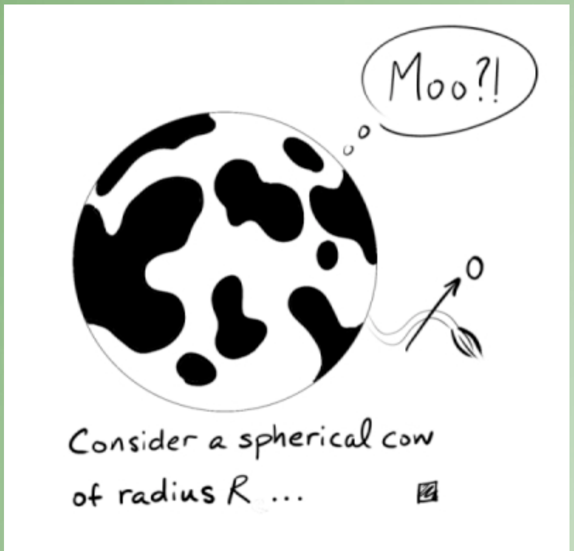


Physics of a Baseball Bat

How would a physicist pick out a baseball bat?



Physics of a Baseball Bat

How would a physicist pick out a baseball bat?

Physicist's Bat

Ballplayer's Bat

Why are they different?

Physics of a Baseball Bat

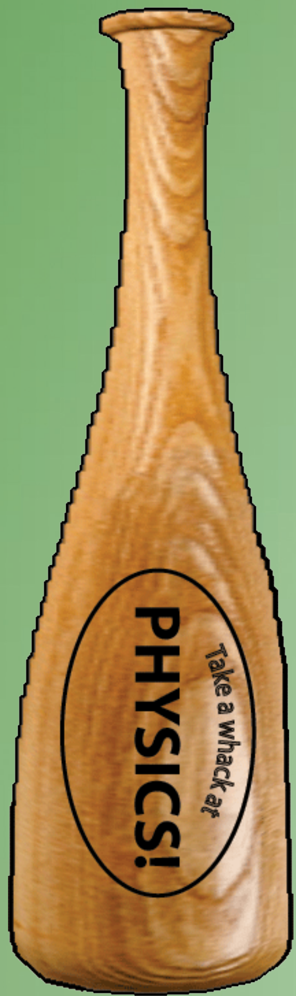
The center of mass (CM)

CM in the middle

Where is the CM of a real bat?

Physics of a Baseball Bat

The center of mass (CM)



Cut out the bat and find its center of mass.

Is it closer to the handle end or the barrel end?

Physics of a Baseball Bat

The center of mass (CM)

CM in the middle

CM is closer to the barrel end

Physics of a Baseball Bat

The rotational inertia (I)

Rotational inertia is a measure of how hard an object is to rotate.

Which is it easier to balance on your hand, the bat or the meter stick?

Physics of a Baseball Bat

The rotational inertia (I)

Rotational inertia is a measure of how hard an object is to rotate.

Which is it easier to balance on your hand, barrel up or barrel down?

Physics of a Baseball Bat

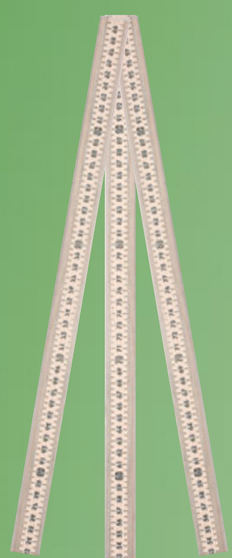
The rotational inertia (I)

The bat has a larger rotational inertia about the handle than the meter stick.

Physics of a Baseball Bat

The center of oscillation (CO)

Physical Pendulum



Simple Pendulum

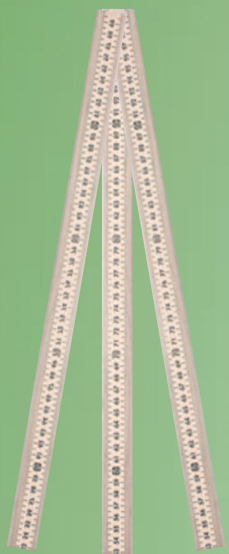
The CO is equal to the length of a simple pendulum with the same period as the bat or meter stick.

Physics of a Baseball Bat

The center of oscillation (CO)

For the meter stick, the CO is 2/3 of the length.

For the bat, the CO is more than 2/3 of the length.



Physics of a Baseball Bat

The rotational inertia (I) calculation

Physical Pendulum

$$T = 2\pi\sqrt{\frac{I}{mgr_{cm}}}$$

Simple Pendulum

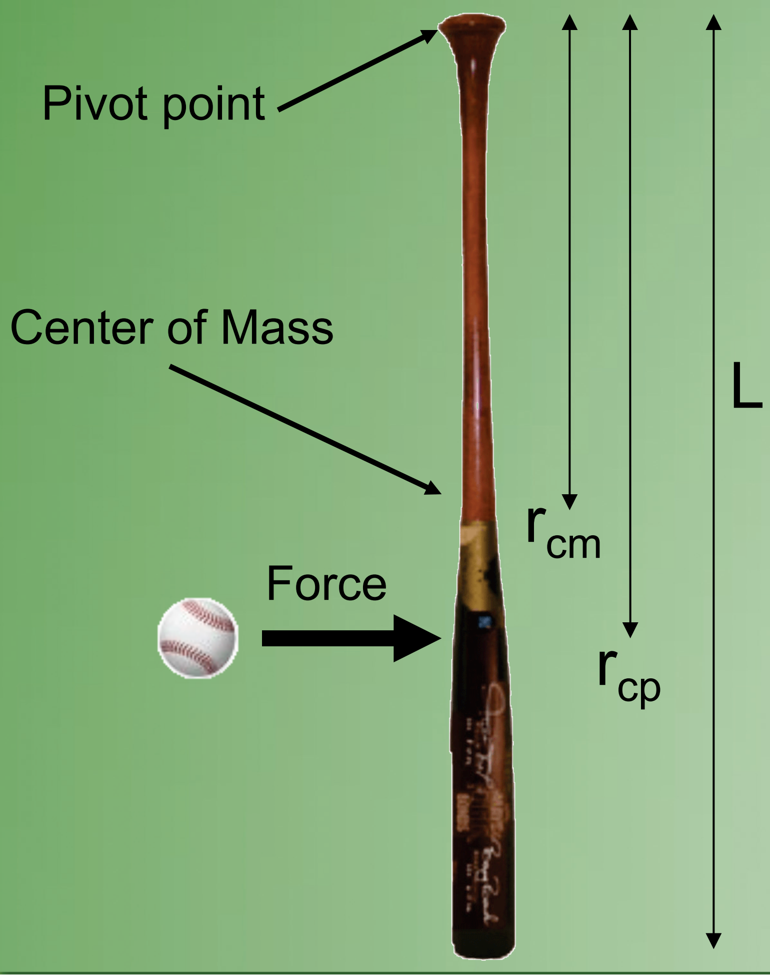
$$T = 2\pi\sqrt{\frac{r_{co}}{g}}$$

$$\sqrt{\frac{r_{co}}{g}} = \sqrt{\frac{I}{mgr_{cm}}} \Rightarrow \frac{r_{co}}{g} = \frac{I}{mgr_{cm}} \Rightarrow I = mr_{co}r_{cm}$$

Physics of a Baseball Bat

The center of percussion (CP)

The spot were an applied force causes pure rotation about the end of the bat



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

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

but… $r_{cp} = \dfrac{mr_{co}r_{cm}}{mr_{cm}} = r_{co}$

Physics of a Baseball Bat

The center of percussion (CP)

We can verify the fact that the CP and the CO are the same.

Physics of a Baseball Bat

The vibrational nodes (VN)

You can demonstrate vibrational nodes with a stick that is more flexible than a bat.

Physics of a Baseball Bat

The vibrational nodes (VN)

Physics of a Baseball Bat

The vibrational nodes (VN)

Physics of a Baseball Bat

The vibrational nodes (VN)

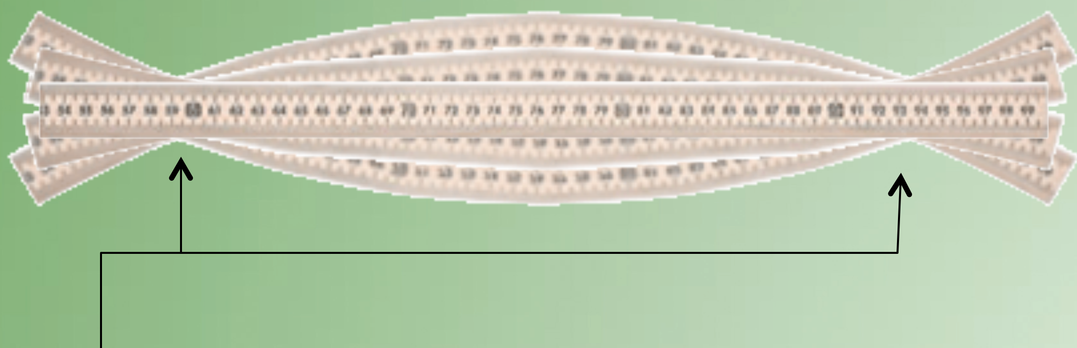
If you wrap a paper megaphone around the top of the bat you can hear the vibrations.

Find the place where the sounds is minimum.

Physics of a Baseball Bat

The vibrational nodes (VN)

The fundamental oscillation of a “free” meter stick.



The nodes are ¼ of the way from each end.

Physics of a Baseball Bat

The vibrational nodes (VN)

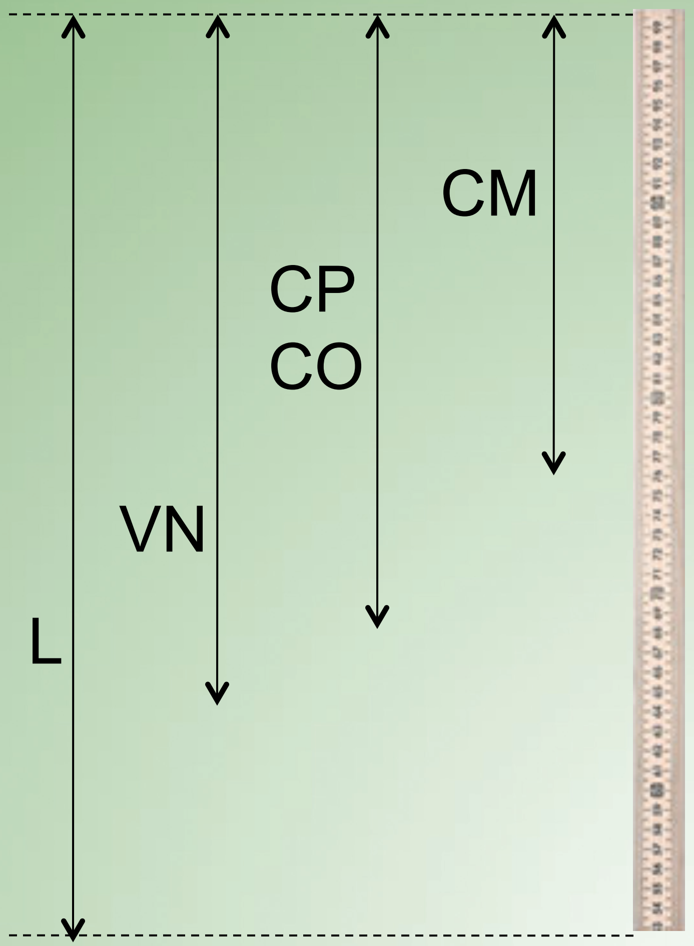
The VN for the meter stick is ¾ of the way down.

The VN for the bat is a bit more than ¾ of the way down.

Physics of a Baseball Bat

Summary of the Physicist's Bat

- Static Properties
- The center of mass (CM)
- The center of oscillation (CO)
- The rotational inertia (I)
- Dynamic Properties
- The center of percussion (CP)
- The vibrational nodes (VN)

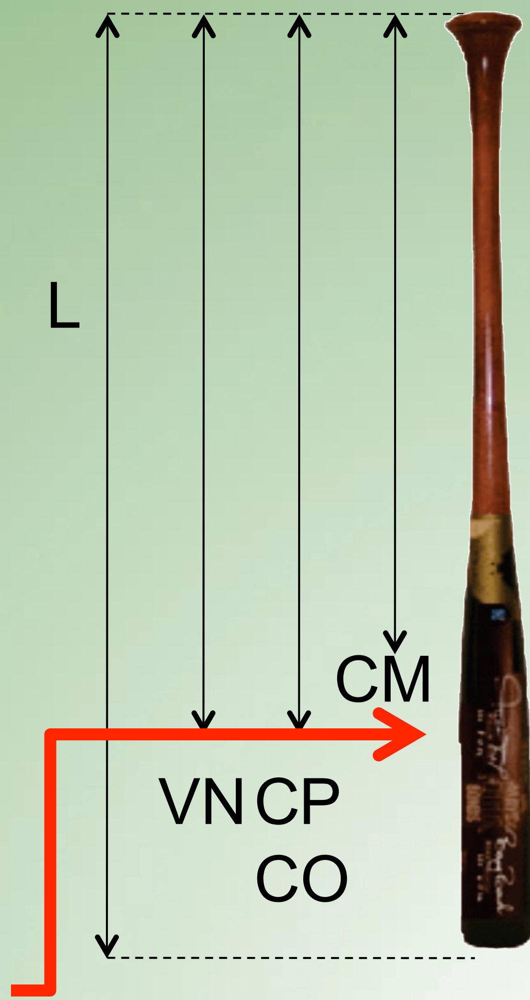


Physics of a Baseball Bat

Summary of the Ballplayer's Bat

- Static Properties
- The center of mass (CM)
- The center of oscillation (CO)
- The rotational inertia (I)
- Dynamic Properties
- The center of percussion (CP)
- The vibrational nodes (VN)

The VN is at the same spot as the CP and CO! This is the "Sweet Spot."



Physics of a Baseball Bat

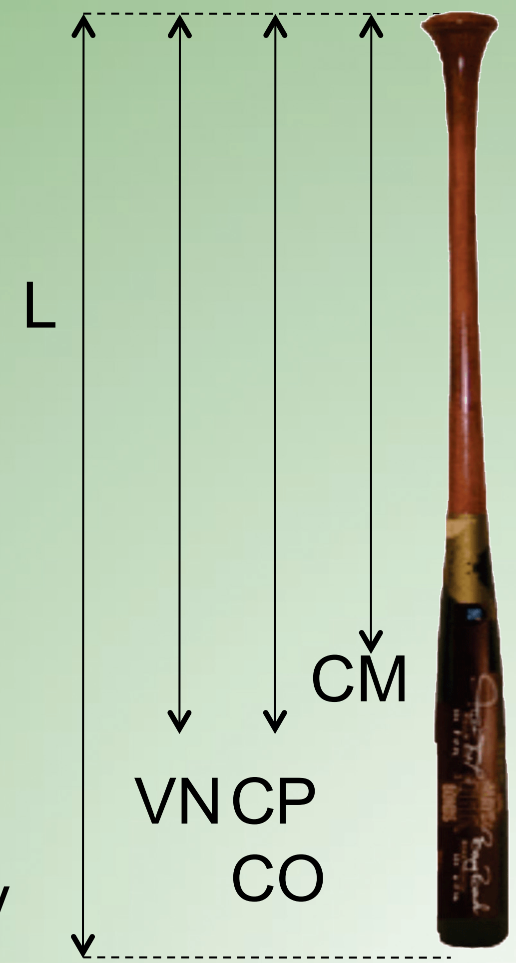
"The Sweet Spot"

A bat has a sweet spot.
A meter stick does not!

During the ball-bat collision, energy is used to vibrate the bat and to exert forces (do work) on your hands.

If the collision occurs at the sweet spot, no energy is used for bat vibrations or to do work on your hands.

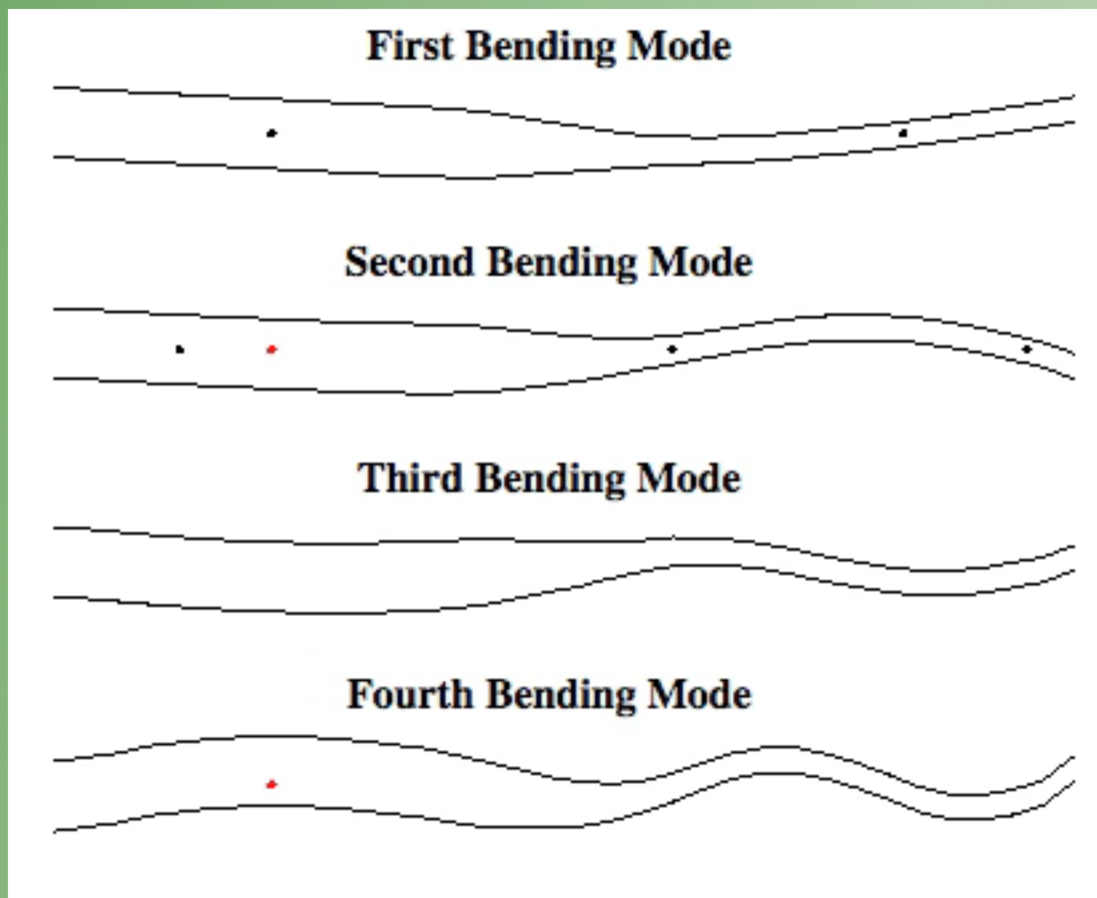
At the sweet spot, the maximum energy is available to go into the ball.



Physics of a Baseball Bat

Aren't aluminum bats different than wooden bats?

The internal vibrations of aluminum bats can be engineered in.



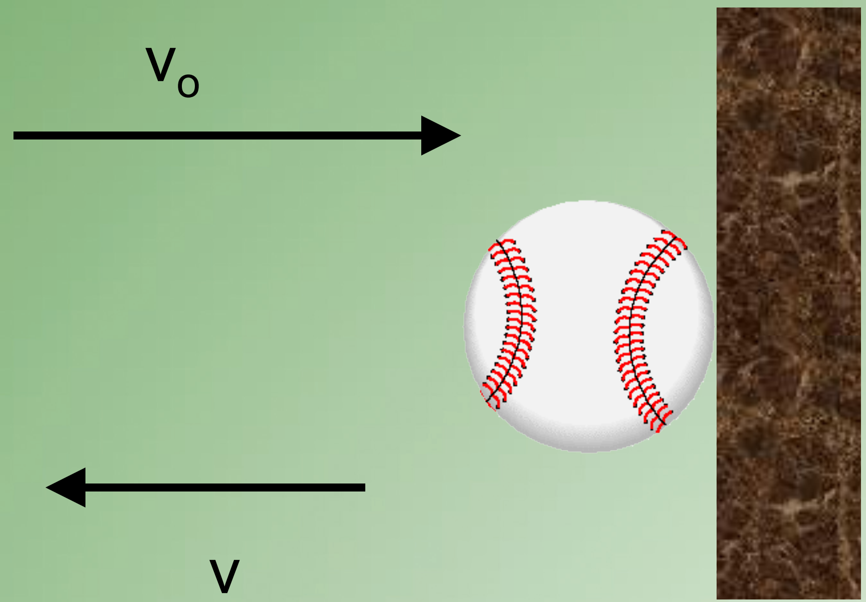
Physics of a Baseball Bat

Drop a “sad” ball on the table. Do you know why it is called a sad ball?

Drop the sad ball on the aluminum can. What happens?

Coefficient of Restitution

$$COR = \frac{v}{v_o}$$



The rules of baseball state that a ball shot at 85ft/s at a wall of northern white ash must rebound with a speed of 54.6% of the initial speed.

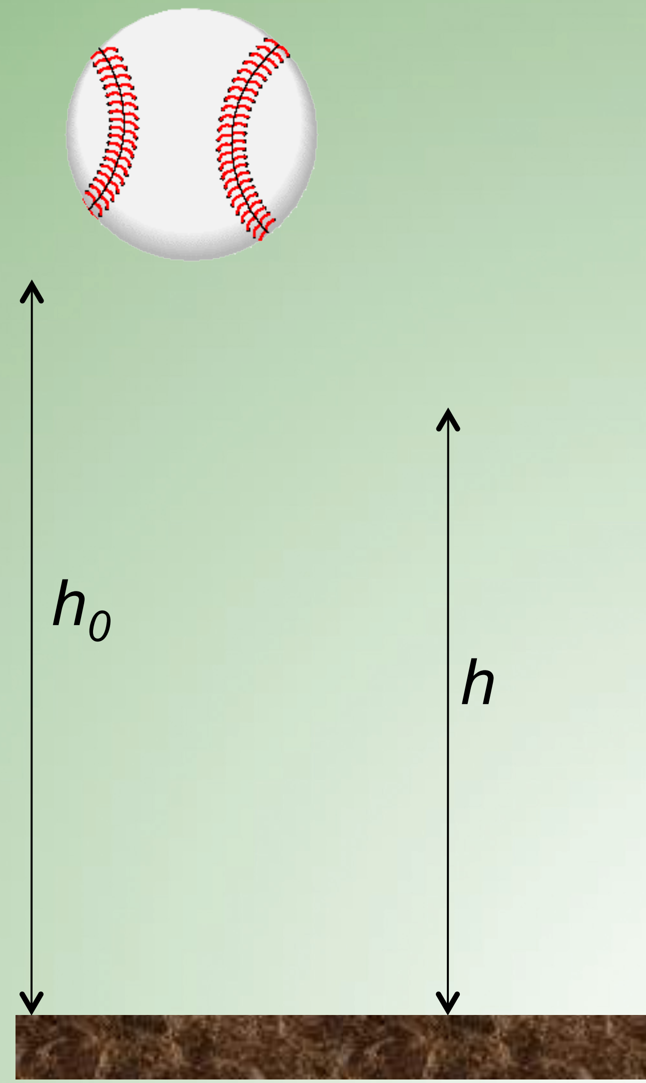
$$COR = 0.546$$

Coefficient of Restitution

$$COR = \frac{v}{v_o}$$

$$v_o = \sqrt{2gh_o} \qquad v = \sqrt{2gh}$$

$$COR = \frac{v}{v_o} = \frac{\sqrt{2gh}}{\sqrt{2gh_o}} = \sqrt{\frac{h}{h_o}}$$



Coefficient of Restitution

$$COR = \frac{v}{v_o}$$

CENCO Coefficient of Restitution Demonstrator

Take Me Out to the Ball Game!

Take Me Out to the Ball Game!

- Take me out to the ball game.
- Take me out with the crowd.
- Buy me some peanuts and Cracker Jack.
- I don’t care if I ever get back,
- cuz it’s root, root, root for the home team.
- If they don’t win it’s a shame.
- For it’s one, two, three strikes, you’re out,
- At the old ball game!

Resources

For more ideas of how to use baseball to teach physics, check out….

laserpablo.com/baseball/baseball.htm

phys.csuchico.edu/baseball