Humidity and the Coefficient of Restitution (COR) of Baseballs

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How it started…..

USA Today May 9th, 2002

Rockies' moister baseballs drying up run production

By Mike Dodd
USA TODAY

Left high and dry in Colorado for nine years, pitchers may now get some help.

The Rockies are experimenting with a new storage system for game baseballs, keeping them in a humidor to prevent them from drying out in Denver's mile-high, humidity-low climate.

"It sounds like a good idea," says Thomas M. Stephen, chairman of the physics department at the University of Denver. "I think it would have an effect, but how much of an effect would be pretty difficult to figure (theoretically)."

Studies have shown that baseballs travel 9% farther in Denver's thin air than at sea level. It's also believed the low humidity dries out the balls, theoretically making them livelier and making the cowhide surface slicker and harder for pitchers to grip.

About three weeks ago, the Rockies started using their new "environmental chamber," storing balls at 40% humidity. (Denver's average afternoon humidity ranges from 34-38% during the baseball season, according to the National Weather Service.) Club President Keli McGregor said the team is trying to maintain the balls in the same condition in which they arrive.

"I just can't understand how Major League Baseball would allow just one team to do that," Montreal Expos manager Frank Robinson said. "It's an advantage. It's not right."

Arizona Diamondbacks GM Joe Garagiola Jr. doesn't see a problem as long as both teams use the same balls.

Is it working? Runs are down dramatically at Coors Field, but it's not likely to dampen hitters' enthusiasm for playing there. The Rockies are hitting .300 at home, third best in the majors. On the road, they're batting .223, ranking 27th.

Contributing: Rod Beaton

▸ **Mixed results in Colorado, 6C**

Down in Denver

Run production at Coors Field is down at least 35% in combined scores.

First seven Aprils	April 2002
15.1 runs per game	9.8 runs per game

▸ Through the first 16 games at Coors, scoring is off 4.69 runs a game — 2.15 runs a game more than the park with the second-biggest run decrease, San Diego's Qualcomm Stadium.

▸ 1.42 fewer home runs per game at Coors, the greatest decrease in the majors.

By Michael Madrid, USA TODAY

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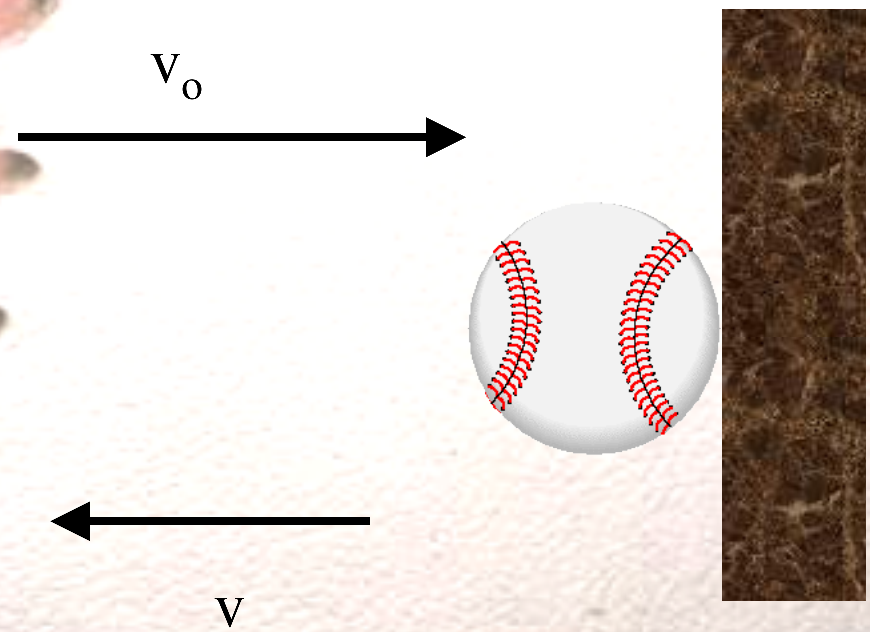
What is the Coefficient of Restitution?

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



What is the Coefficient of Restitution?

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

- If the COR=1 then all the initial kinetic energy remains as translational kinetic energy of the ball.
- If the COR<1 then some of the initial kinetic energy of the ball is transformed into other types of energy such as heat, sounds waves, etc.

What is the Coefficient of Restitution?

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 ± 3.2% of the initial speed.

$$COR = 0.546 \pm 0.032$$

Why Does COR Vary With Humidity?

Inside the cover are many layers of yarn.

It is postulated that a humid environment allows the yarn to take up water.

The water makes the yarn less resilient allowing it to absorb a greater fraction of the energy of a collision.

How Does the Humidity Affect the Range?

$$\Delta R = \frac{dR}{d(RH)} \Delta RH$$

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- The launch speed depends on the COR so we need to study the ball-bat collision.

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- The range depends on launch speed so we need to examine the flight of the ball.
- The launch speed depends on the COR so we need to study the ball-bat collision.
- The COR depends on the humidity so we need to measure COR.

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*D. T. Kagan, “The effects of coefficient of restitution variations on long fly balls,” Am. J. Phys. **58**, 151-154 (1990)

How Do You Measure COR?

www.astm.org

Founded in 1898, ASTM International is a not-for-profit organization that provides a global forum for the development and publication of voluntary consensus standards for materials, products, systems, and services.Over 30,000 individuals from 100 nations are the members of ASTM International, who are producers, users, consumers, and representatives of government and academia. In over 130 varied industry areas, ASTM standards serve as the basis for manufacturing, procurement, and regulatory activities. Formerly known as the American Society for Testing and Materials, ASTM International provides standards that are accepted and used in research and development, product testing, quality systems, and commercial transactions around the globe.

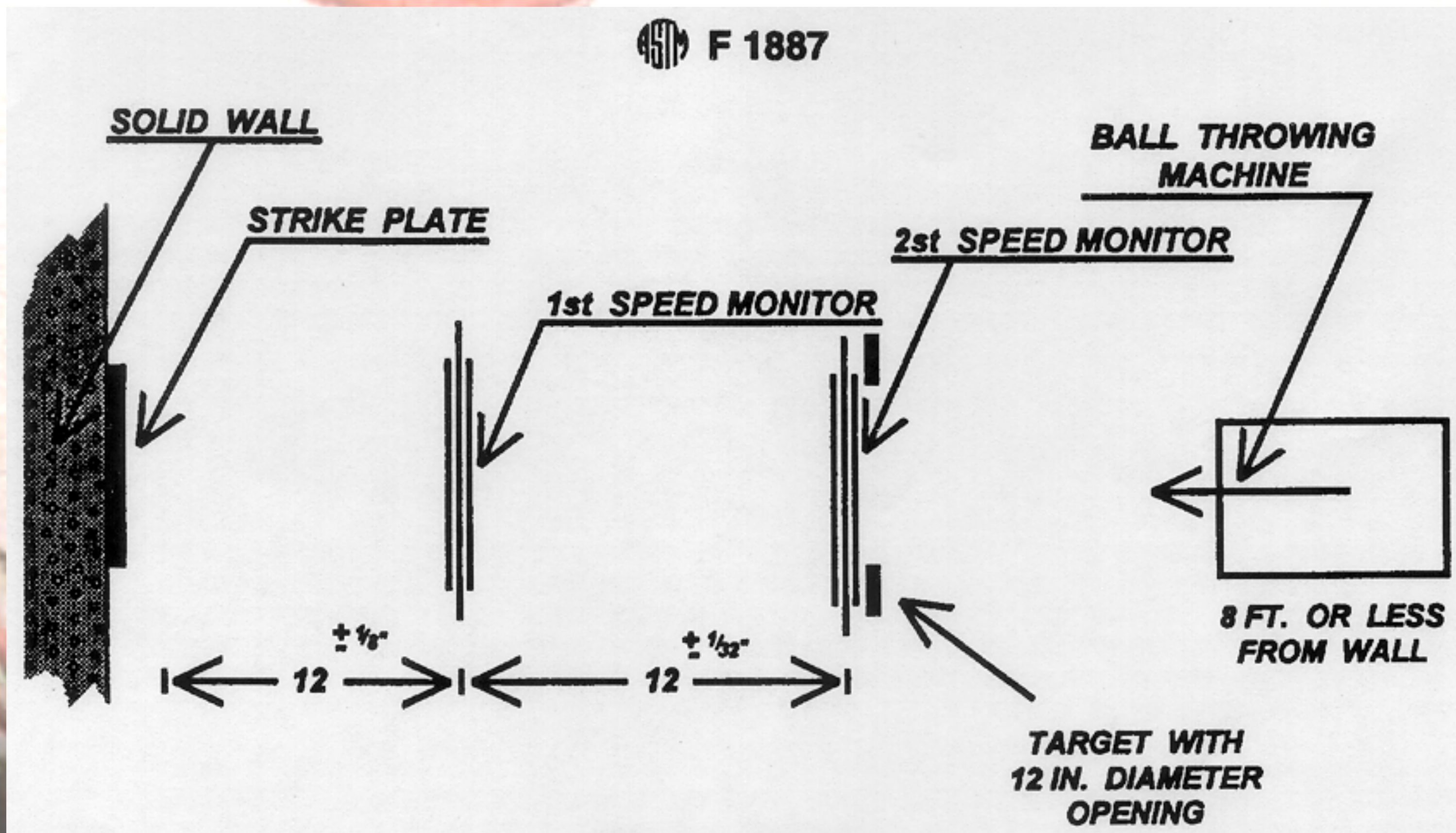
How Do You Measure COR?

Designation: F 1887 – 98

Standard Test Method for Measuring the Coefficient of Restitution (COR) of Baseballs and Softballs[1]

This standard is issued under the fixed designation F 1887; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

How Do You Measure COR?



How Do You Measure COR?

Lansmont Corporation

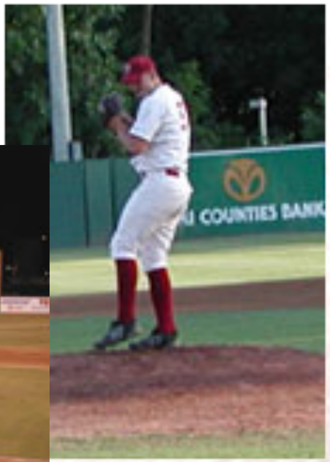
Lansmont Corporation was founded in 1971 to foster significant advancements in the emerging product and package dynamics testing industry. Today, Lansmont operates multiple facilities and is recognized globally as the undisputed leader in this specialized industry.

www.lansmont.com

Ball COR Testing

This test is performed per ASTM procedure F 1887 in an environmentally controlled laboratory using components of the Lansmont Bat Testing System (BTS). The test may be performed at any impact speed up to 120 mph. The balls can be conditioned to any desired temperature and humidity prior to testing.

How Do You Measure COR
….With Very Little Money?



Work at a university with an outstanding baseball program!

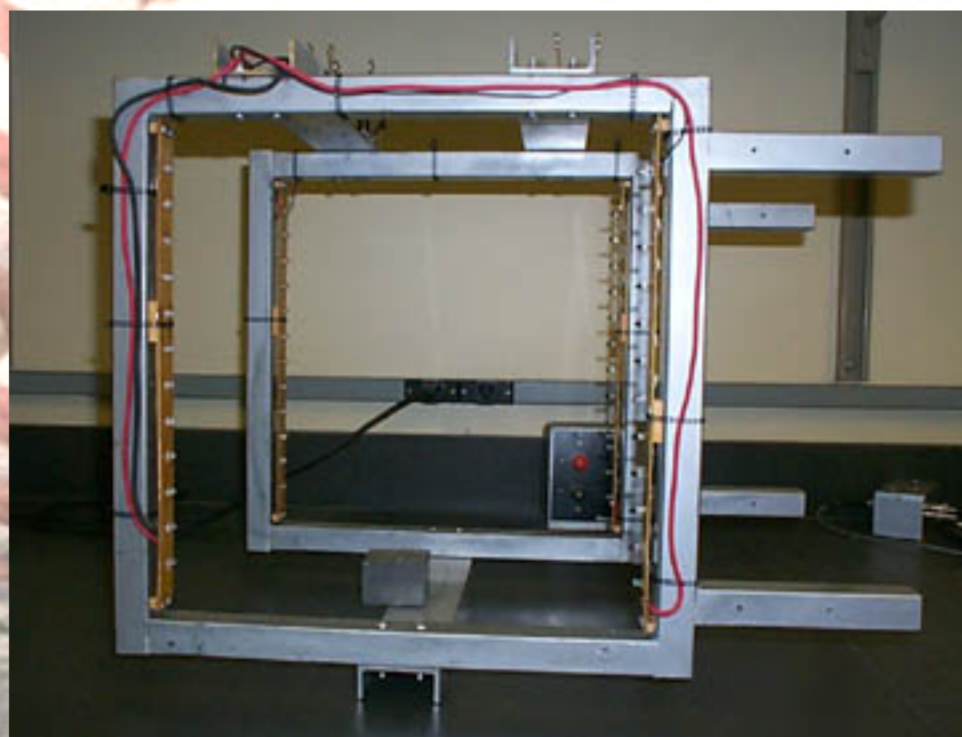
(and a supportive coach:
Lindsay Meggs)

How Do You Measure COR
….With Very Little Money?

Borrow the pitching machine from the baseball team.

How Do You Measure COR
….With Very Little Money?

Build a speed trap out of spare parts.



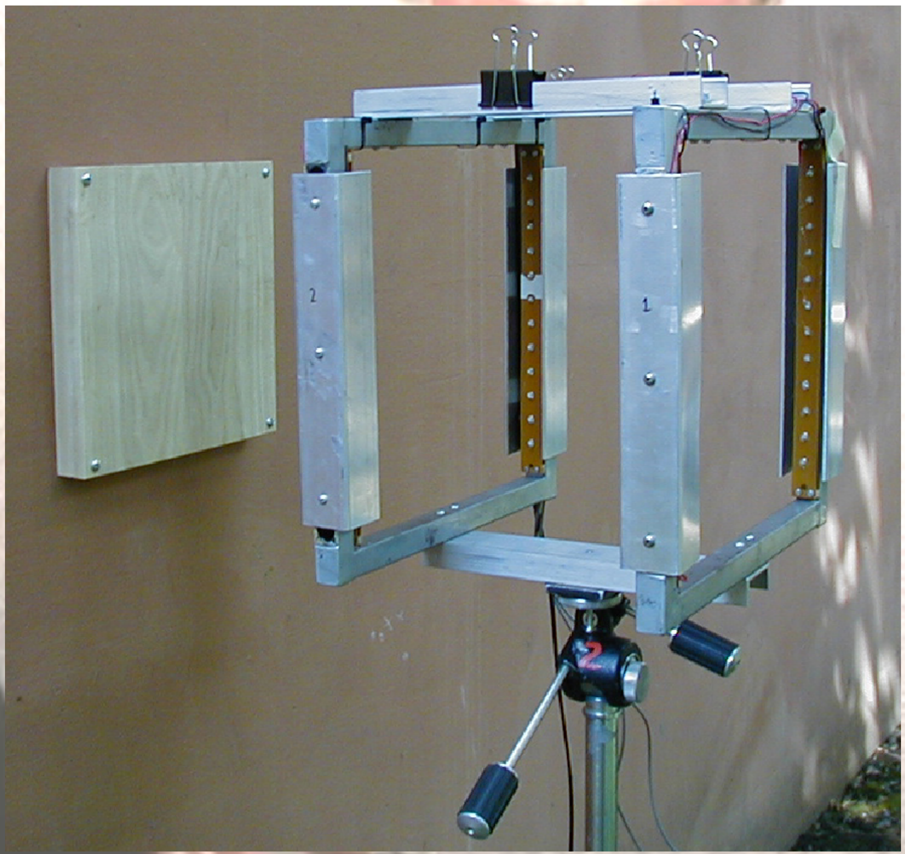
How Do You Measure COR ….With Very Little Money?

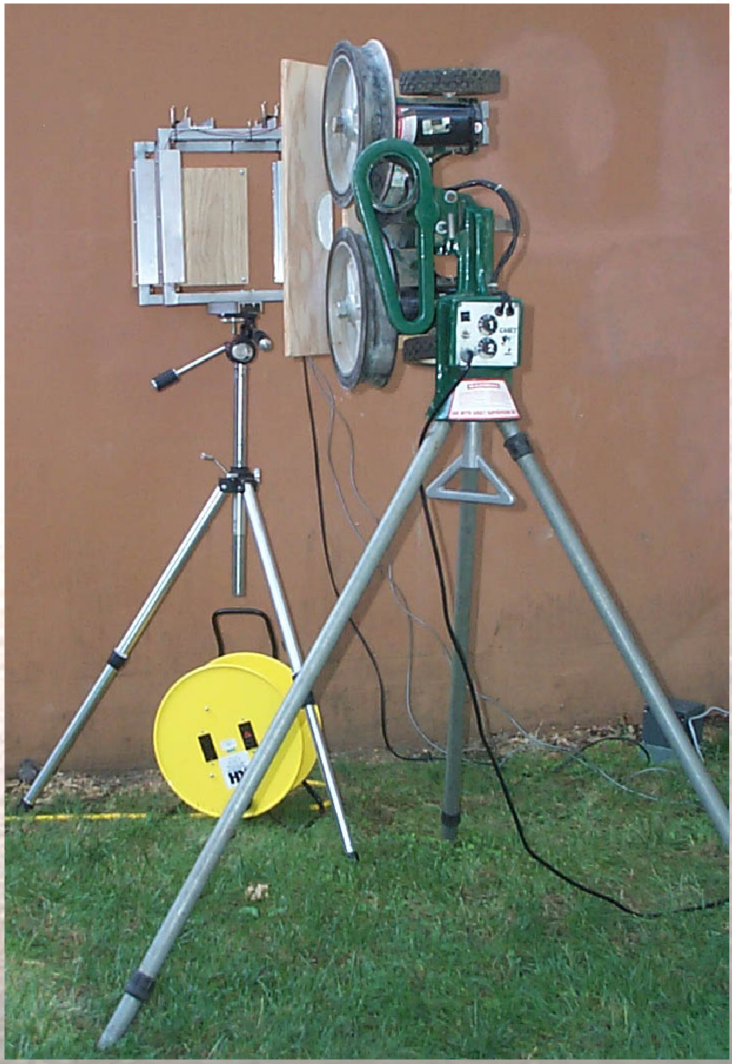
Beg enough money to buy a few dozen new baseballs.

How Do You Measure COR
….With Very Little Money?

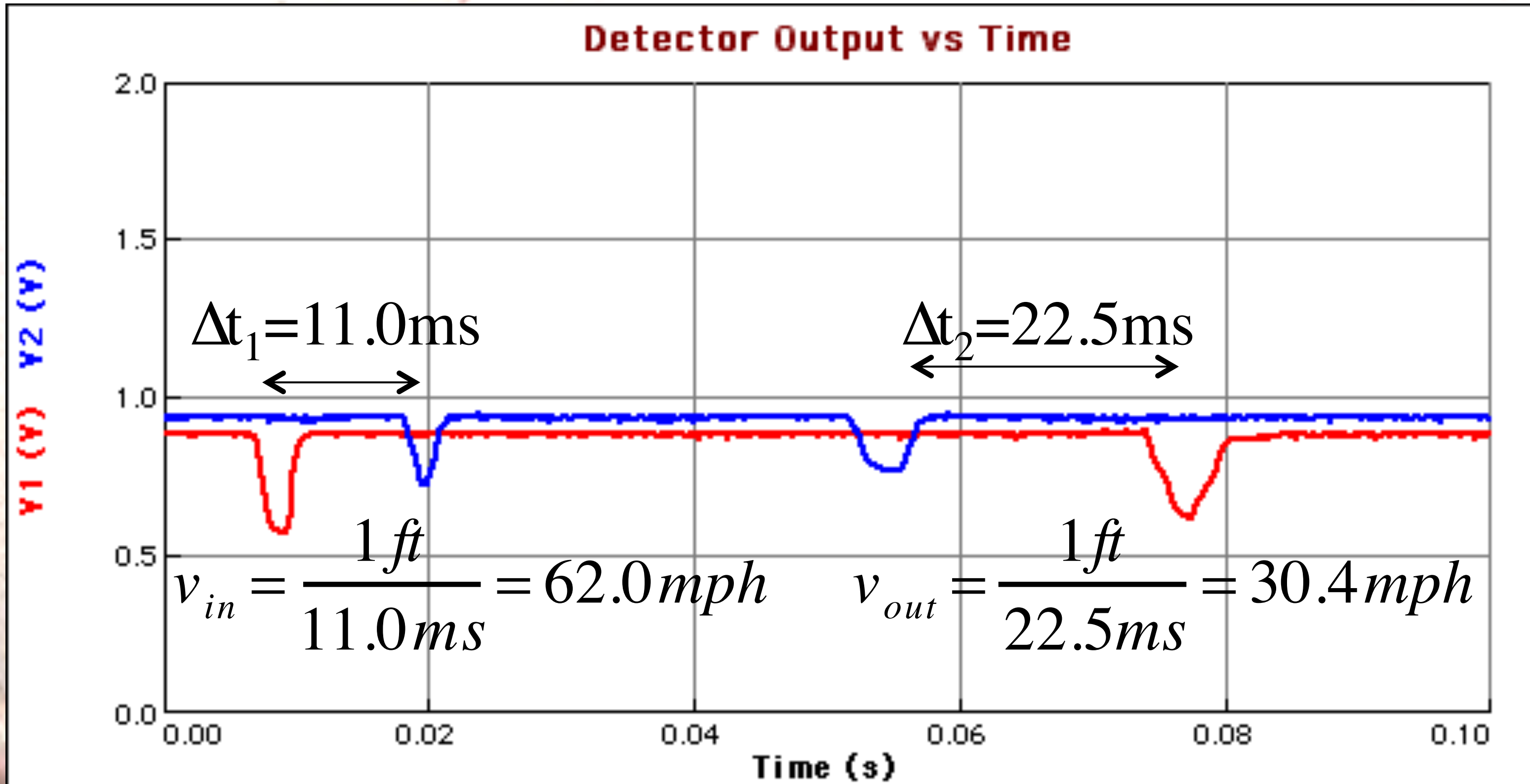
Borrow desiccators from the Chemistry Department.

The Experiment





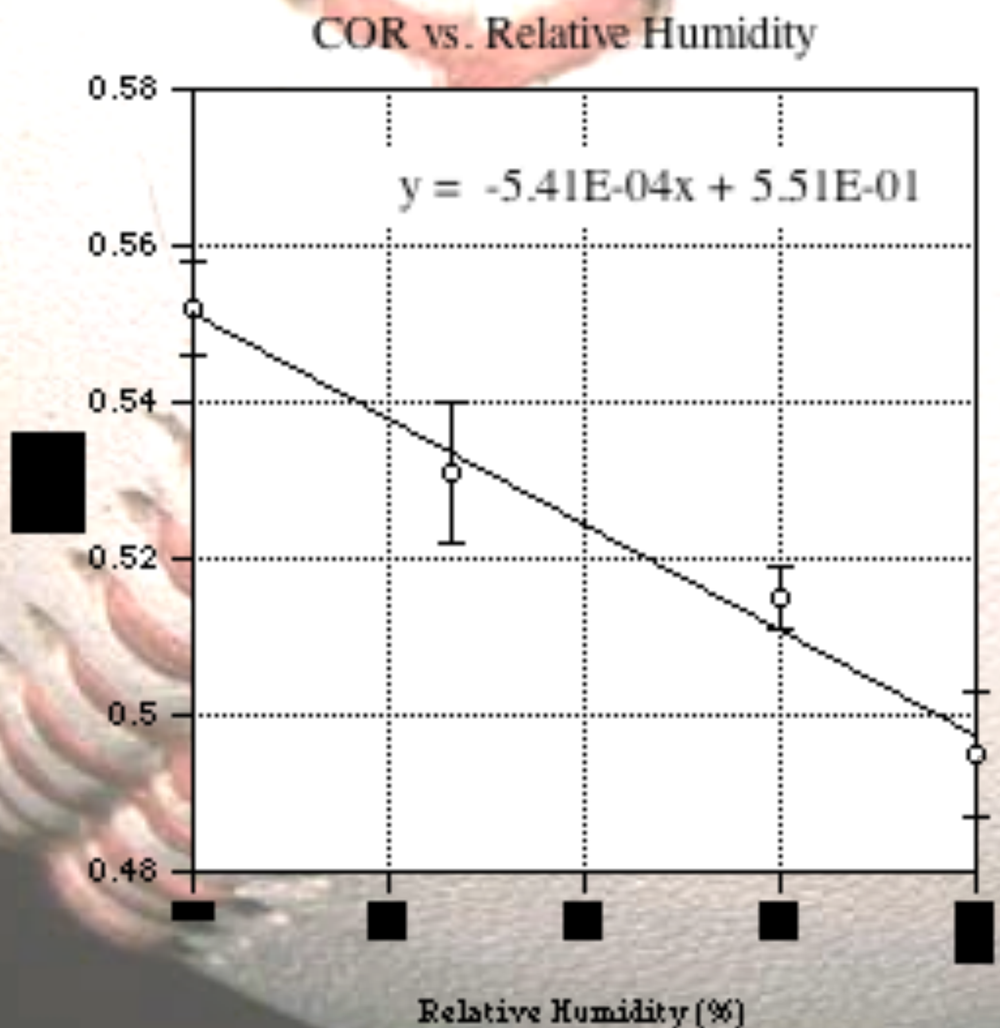
The Experiment - Typical Data



$$v_{in} = \frac{1\,ft}{11.0\,ms} = 62.0\,mph \qquad v_{out} = \frac{1\,ft}{22.5\,ms} = 30.4\,mph$$

$$COR = \frac{30.4\,mph}{62.0\,mph} = 0.491$$

The COR vs. Relative Humidity

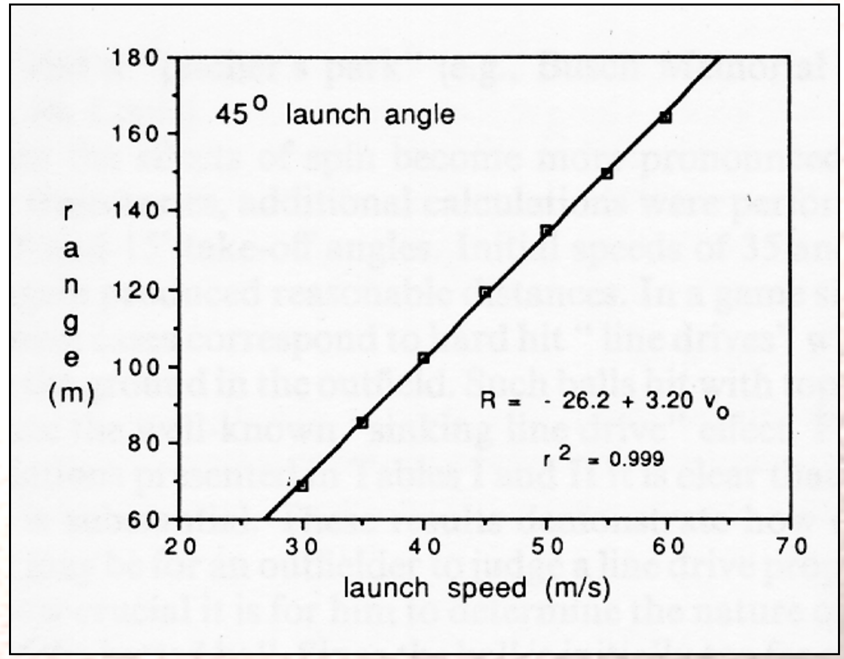


$$\frac{d(COR)}{d(RH)} = -5.4\text{x}10^{-4}$$

The Flight of the Ball

The Range Equation indicates that the range is proportional to the square of the launch speed for a given angle.

$$R = \frac{v^2}{g}\sin 2\theta$$



Keeping track of air resistance produces a nearly linear relationship for a given launch angle.

$$\frac{dR}{dv} \approx 3.20s$$

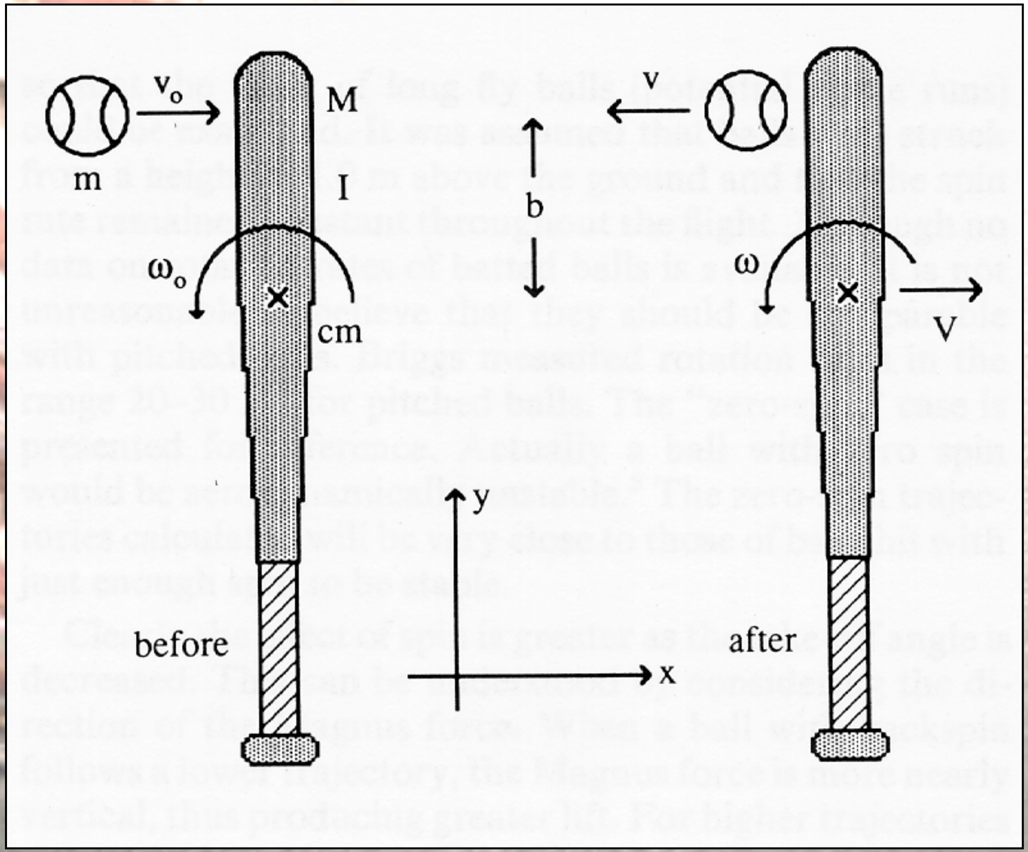
The Flight of the Ball

The variation of range with launch speed as a function of launch angle.

Launch angle	Slope $= \frac{dR}{dv}$
30°	3.29 s
35°	3.32 s
40°	3.28 s
45°	3.20 s
50°	3.06 s
55°	2.84 s
60°	2.60 s

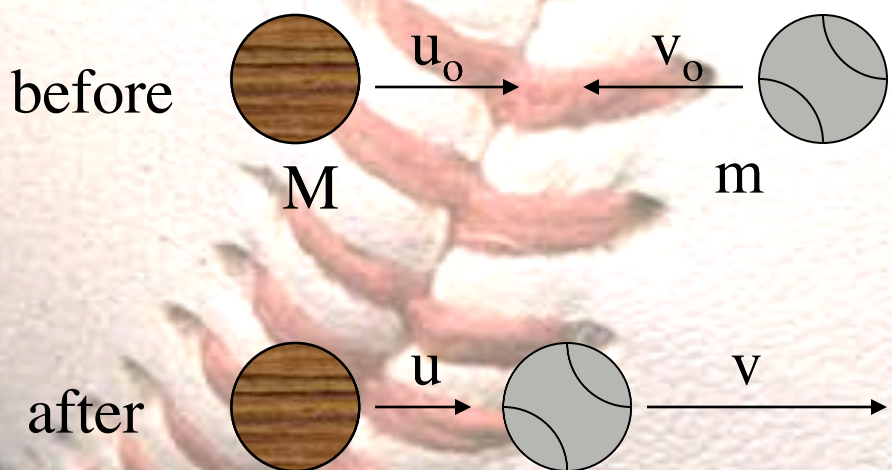
The Ball-Bat Collision

Now we need the variation of the launch speed with COR.
This depends upon the details of the ball-bat collision.



The Ball-Bat Collision

Since well hit balls are struck near the cm of the bat and we don't care about the launch velocity (only its variation with COR) we can model the bat and ball as point masses.



Definition of COR

$$COR = \frac{v - u}{v_o + u_o}$$

Conservation of Momentum

$$Mu_o - mv_o = Mu + mv$$

The Ball-Bat Collision

Combining the equations to eliminate the final speed of the bat and solve for the final speed of the ball,

$$v = \frac{COR(v_o + u_o) + u_o - \frac{m}{M} v_o}{1 + \frac{m}{M}}$$

Differentiating yields the desired result,

$$\frac{dv}{d(COR)} = \frac{v_o + u_o}{1 + \frac{m}{M}} \approx \frac{65\ {}^{m}\!/\!_{s}}{1 + \frac{0.15}{1}} \approx 55\ {}^{m}\!/\!_{s}$$

The Results

Putting it all together,

$$\Delta R = \frac{dR}{dv} \cdot \frac{dv}{d(COR)} \cdot \frac{d(COR)}{d(RH)} \Delta RH$$

Recall, $\dfrac{d(COR)}{d(RH)} = 5.4\text{x}10^{-4}$

$$\frac{dR}{dv} = 3s$$

$$\frac{dv}{d(COR)} = 55\,m/s$$

The Results

Putting it all together,

$$\Delta R = \frac{dR}{dv} \cdot \frac{dv}{d(COR)} \cdot (5.4 \times 10^{-4})\Delta RH$$

Recall,

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$$\Delta R = (3s) \cdot \frac{dv}{d(COR)} \cdot (5.4 \times 10^{-4})\Delta RH$$

Recall,

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The Results

Putting it all together,

$$\Delta R = (3s)\cdot(55m/s)\cdot(5.4\times10^{-4})\Delta RH$$

The Results

Putting it all together,

$$\Delta R \approx (8.9\frac{cm}{\%RH})\Delta RH$$

At the extreme, the humidity will change by 100%,

$$\Delta R \approx (8.9\frac{cm}{\%RH})(100\%) \approx 8.9\,m \approx 29\,ft$$

The Results

The Physics of Baseball
Robert Adair

"…long flies hit with balls stored under conditions of extreme humidity could be expected to fall as much as 30 feet short of the distance expected for normal balls."

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Stats for the Colorado Rockies

Year	Team Home Run Ranking	Team ERA Ranking
2003	8th	28th
2002	22nd	28th
2001	4th	29th
2000	25th	26th