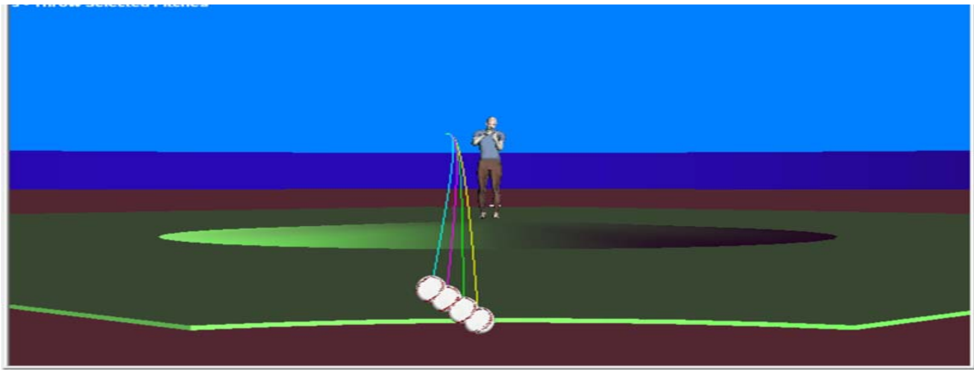
The Visual Physics of Baseball ©



By Clifton Neeley

The above illustration is actually a picture of a baseball being thrown digitally through four different weights of air. Baseball enthusiasts and statisticians alike have long been asking questions concerning how much additional ball movement a pitcher gets in different climatic conditions. Most of the discussion has centered around the distance a ball flies when hit at a high altitude location. However, the pitcher also gains additional hop on the fastball and curve on the curveball due to additional air density. Air density is the product of barometric pressure due to altitude, temperature and humidity. Temperature is the most effective attribute of air causing additional ball movement for the pitcher; followed by altitude and finally humidity, which affects ball movement only slightly. Denver, Colorado gets the most attention in discussions because the air is very light in comparison to sea level locales, however there are increments of air weight in between the highest altitudes and sea level which create additional criterion from which to analyze ball movement. These more subtle differences in climate between the extremes, have a huge impact on the game of baseball.

These illustrations are from our web site at www.baseballvmi.com which is a website for active fantasy baseball managers and baseball players and managers alike. In the website, there are a number of video illustrations taken from a ballistics launch-type computer program utilizing physics formulas for baseball.

This representation was provided to Clifton Neeley by Paulin Research, Houston, Texas, Mr. Tony Paulin, PE. The program utilizes physics formulas from the Physics of Baseball, by Dr. Robert Adair, as well as, studies by doctoral program students and known formulas in the engineering and aeronautics industries. The depiction is similar to a point to point launch of a ballistic missile or other projectile, converted to match the cover, weight, shape, density and circumference of a spinning baseball projected through the properties of natural air. Sincere thanks to Mr. Tony Paulin.

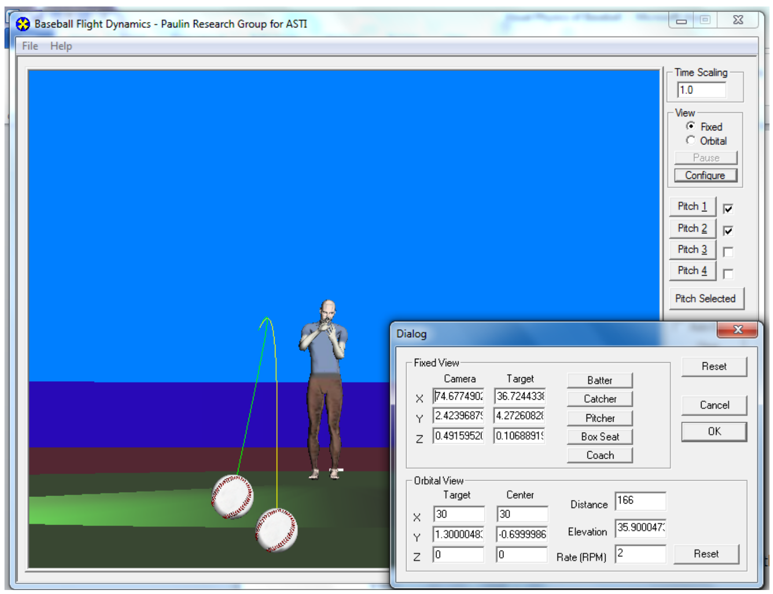
Mr. Paulin also utilized the NeeleyAir gauge formulas of Clifton Neeley, Air Resistance Technologies, Inc., Air Chamber Facilities, Inc., Altitude Sports Triages, Inc. in collaboration with Dr. Douglas Hittle, Professor Emeritus, Colorado State University; Gregory Martino, PE, Greeley, CO; Jonathan Rafacz, Dr. Feng Wang, Dr. Todd Sandrin, Arizona State University; Gene Vosteen, Foxstone Industries, Inc. Many thanks to all these people who collaborated to help with this project.

The following is a physics demonstration of how much additional ball movement a pitcher will have in his arsenal if he is pitching in cooler, drier air at sea level in comparison to warmer, more humid air at 1,000 feet elevation such as Atlanta. The depiction is real. The pitch is a four-seam fastball. Other pitches will be likewise affected.

Combined Climate on pitch movement

The first pitch, identified by the yellow line is a pitch in the following conditions:

a. **Temperature = 90 degrees**
b. **Humidity = 80%**
c. Speed = 90 mph
d. Revolutions Per Minute (RPM level) = 2000
e. **Elevation = 1000 ft.**
f. NeeleyAir Gauge Reading = 54



The second pitch, identified by the green line is precisely the same pitch, by the same pitcher but in a climate with the following conditions: we change the **elevation to sea level, the humidity to 20%, and the temperature to 60 degrees Fahrenheit**. NeeleyAir Gauge Reading = 70

A hitter, conformed to the climate depicted in the first pitch, would (more times than not) swing at this second pitch and potentially miss, foul off, or break the handle of his bat on this pitch. The fastball is on him too quickly (.41 seconds from the pitcher to the plate) and breaks too late (20 feet in front of the plate or less) for the hitter to adjust his swing, or choose not to swing, which must be already in motion 30-40 feet in front of the plate.

The questions abound. Why can't hitters and pitchers simply adjust to this additional ball movement and play the game as normal? How much additional ball movement is attributed to humidity? How much to altitude? How much to temperature? Does this actually interfere with competition, or does it enhance competition? Nothing can be done about this phenomenon, so why bother with the analysis?

The truth is, pitchers are being compared to each other in the form of era's without the benefit of having additional movement on the pitch for half of the games they pitch. Also, when they switch climates drastically, the additional movement affects the preciseness of their control. This affects their contracts and their longevity in the league in comparison to those pitchers who have additional movement awarded to them by the climate into which they have been fortunate enough to be drafted or traded.

When one team is adjusting and the other team is not, then the competition is jaded. It takes three games to adjust to the opponents' climate when a team travels from a substantially different climate. It takes three full series for a minus .500 team to adjust to their normal scoring after having played in a substantially different climate and two full series for a plus .500 team. If the adjustments were equal for all teams throughout each 162 game season, then the competition would not be jaded, however that is not the case.

An additional truth is; something can be done about this phenomenon. A practice facility where climates can be duplicated would be a simple and relatively inexpensive solution to allow players daily exposure to necessary adjustments. When all players are allowed to be exposed to the opponents' climate for practice then, and only then, will a team's talent be the reason for its success.

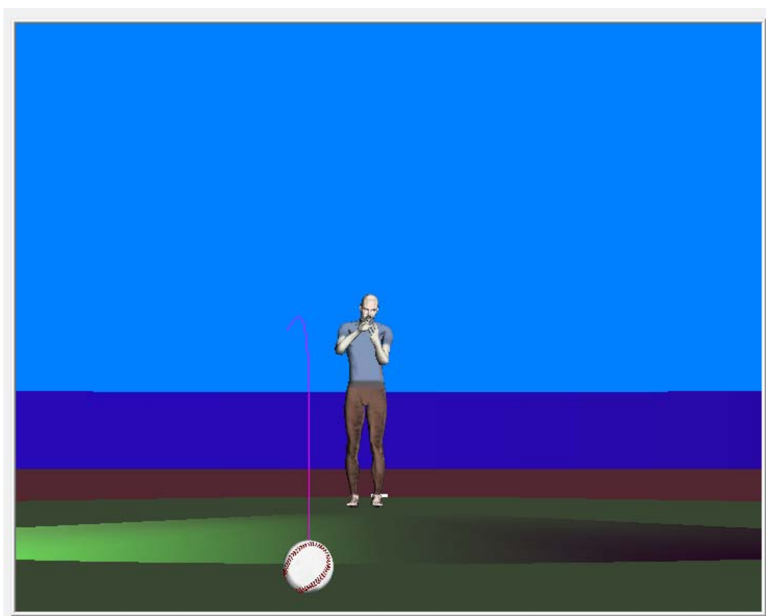
Temperature Effects on Pitch Movement

Let's take a look at the actual impact each ingredient (temperature, humidity and altitude air pressure) of air density has on a baseball pitch.

a. **Temperature = 90 degrees**
b. Humidity = 50%
c. Speed = 90 mph
d. Revolutions Per Minute (RPM level) = 2000
e. Elevation = Sea Level
f. NeeleyAir Gauge Reading = 60

Pitch 1: Four-Seam Fastball, RH pitcher

Let's first view a pitch at 90 mph, in 50% humidity, 90 degree temperature (f) at sea level. Let's use a pitcher who puts a 2000 rpm rate of revolution on the pitch at a 70 degree arm angle. This is how the pitch reacts to the air.



Pitch 2: All same parameters except; we change the temperature to **60 degrees**.
NeeleyAir Gauge Reading = 69

Now let's compare this pitch to the same pitch having changed only the temperature to 60 degrees (f).

This is the amount of adjustment the hitter must make in his muscle memory for a 30 degree temperature change.

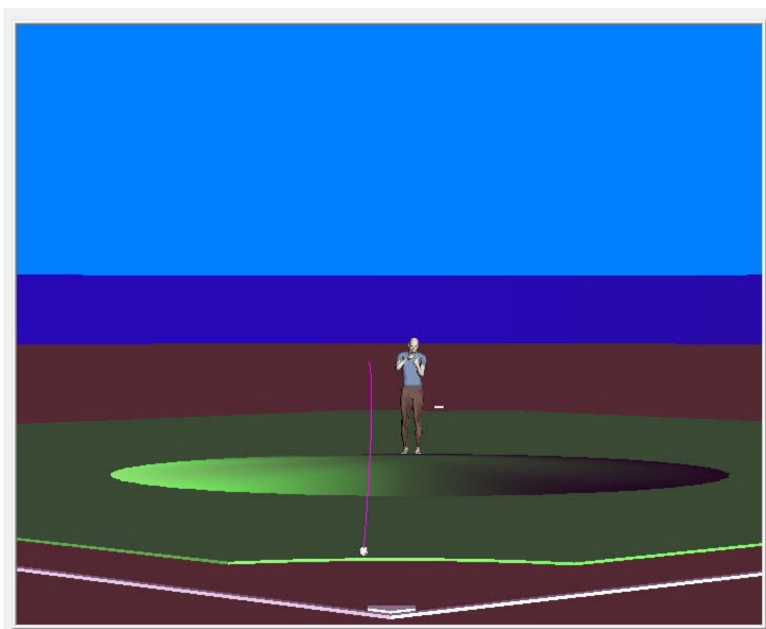
Humidity Effects on pitch movement

Let's take a look at the actual impact of humidity in air density has on a baseball pitch.

a. Temperature = 90 degrees
b. Humidity = 80%
c. Speed = 90 mph
d. Revolutions Per Minute (RPM level) = 2000
e. Elevation = Sea Level
f. NeeleyAir Gauge Reading = 58

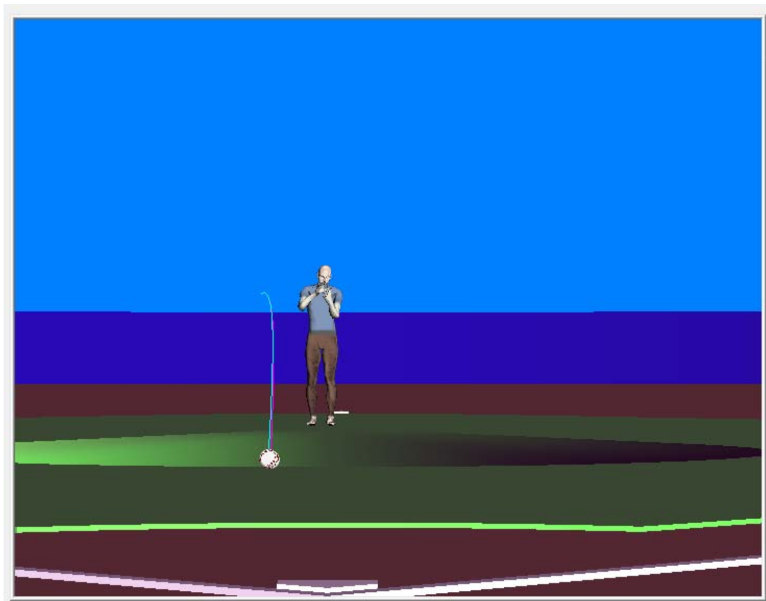
Pitch 1: Four-Seam Fastball, RH pitcher

Let's first view a pitch at 90 mph, in 80% humidity, 90 degree temperature (f) at sea level. Let's use a pitcher who puts a 2000 rpm rate of revolution on the pitch at a 70 degree arm angle. This is how the pitch reacts to the air.



Pitch 2: Now we will use all the same parameters except; we change the **humidity to 20%.** NeeleyAir Gauge Reading = 62

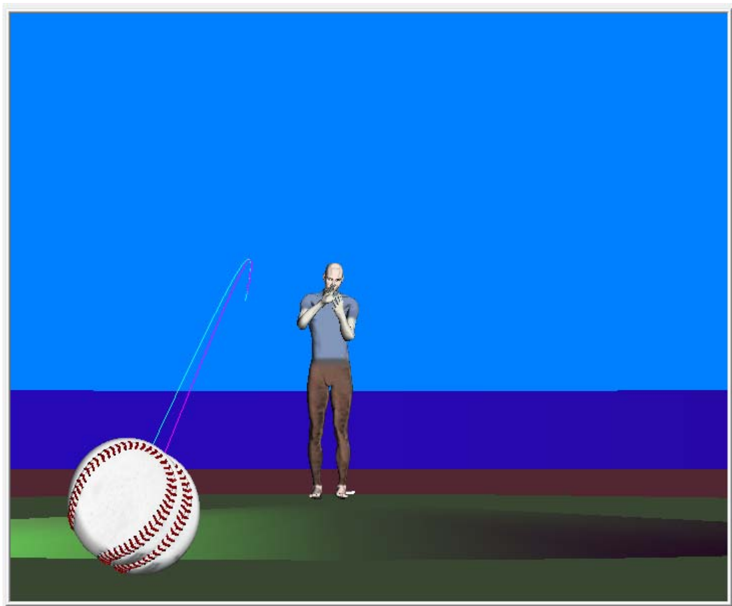
Let's compare this pitch to the same pitch having changed only the humidity to 20% from the original 80%.



This representation requires we take a close-up view of the two pitches. As you can see, humidity affects the pitch very little.

Humidity is in gaseous form. Air molecules are spaced apart by repelling each other in correlation to the air pressure afforded by the elevation. Colder temperatures allow for the molecules to be spaced closer together. However, as humidity is forming, lighter hydrogen molecules begin attaching to oxygen molecules and as a result, heavier nitrogen molecules are replaced by the hydrogen. Therefore, the weight of the air becomes lighter until precipitation forms into fog or clouds. Humid air feels heavy to the living body, but is not heavier for a baseball to fly through. Less air resistance is afforded to the pitcher in humid air.

Close-up view



This is the amount of adjustment the hitter must make in his muscle memory for a 60% humidity change, from higher (80%) to lower (20%) relative humidity.

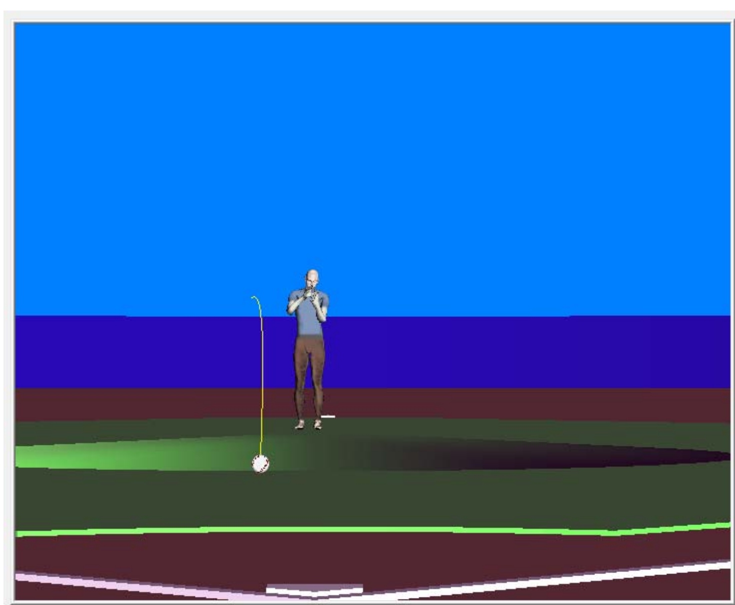
Altitude Effects on pitch movement

a. Temperature = 90 degrees
b. Humidity = 50%
c. Speed = 90 mph
d. Revolutions Per Minute (RPM level) = 2000
e. Elevation = 1000 ft.
f. NeeleyAir Gauge Reading = 55

Pitch 1: Four-Seam Fastball, RH pitcher

Most baseball enthusiasts are well aware of the extremes between Denver and sea level in altitude in general terms of ball movement, but how does only 1000 feet elevation differ from sea level?

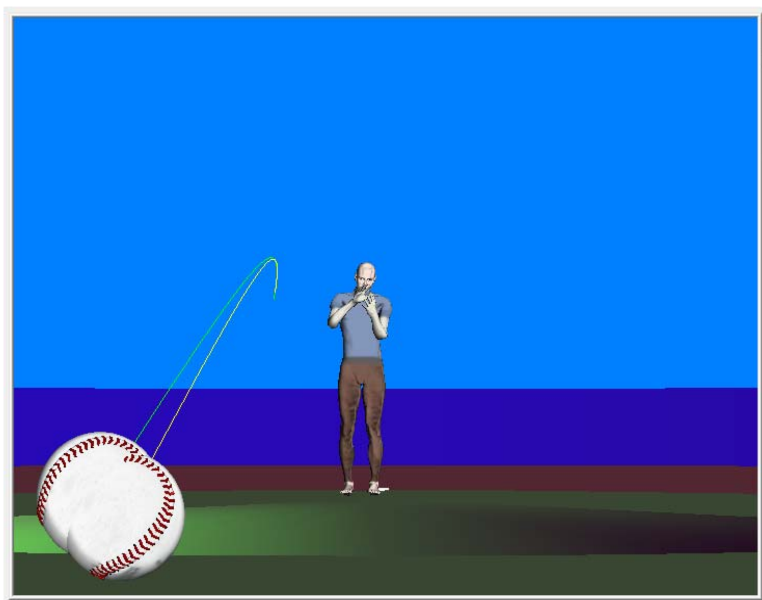
Let's first view a pitch at 90 mph, in 50% humidity, 90 degree temperature (f) at 1,000 ft. elevation. Let's use a pitcher who puts a 2000 rpm rate of revolution on the pitch at a 70 degree arm angle. This is how the pitch reacts to the air.



Pitch 2: Now we will use all the same parameters except; we change the **elevation to sea level**. NeeleyAir Gauge Reading = 60

Let's compare this pitch to the same pitch having changed only the elevation to sea level.

This is the amount of adjustment the hitter must make in his muscle memory for a 1,000 ft. elevation change and the accompanying additional ball movement. One thousand feet matches the stadiums at Atlanta, Phoenix, Milwaukee, Minnesota, and relatively close to Kansas City, Arlington, Detroit, Chicago, Cincinnati, Cleveland, Los Angeles' Chavez Ravine and Pittsburgh.



Four-Seam Fastball, RH pitcher

So, we have seen that **30 degrees drop in temperature** will cause a fastball to lift or hop an **additional 1-1/2 inches**. This would correlate to approximately ½ inch for every 10 degrees of cooler air. We've seen that a **humidity drop of 60% toward drier air**, will account for only about a **3/8 of an inch additional mov**ement or 1/8 inches for every 20% humidity change. By itself, this is miniscule and presumably has little or no effect on the outcome of a baseball game. And, we have also seen that **1,000 feet of altitude differential** compared to sea level will change the ball movement by approximately **¾ of an inch**.

However, in baseball we rarely see these effects one at a time, but normally in combination with each other. So, let's take a look at the amount of additional ball movement that a team stationed at Atlanta, Phoenix or Kansas City, normally playing in 90 degree temperatures and 80% humidity, would witness if they switched to sea level for a series in 60 degree temperatures and 20% humidity.

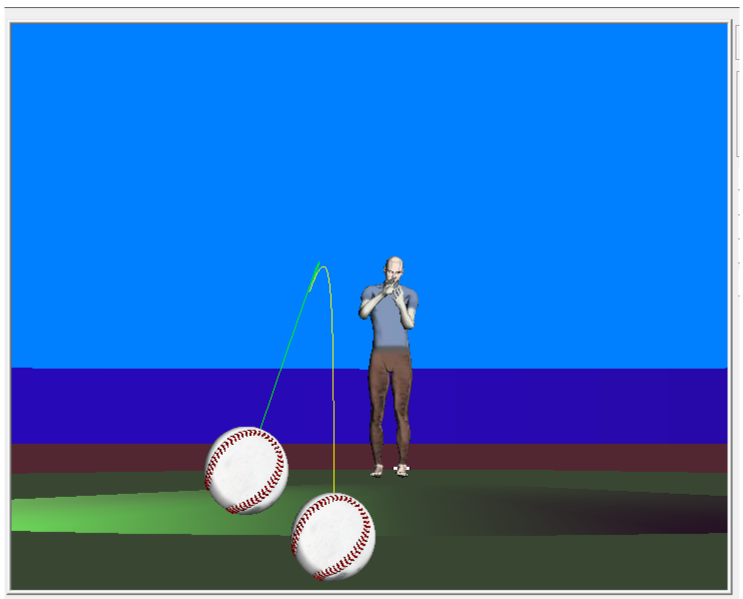
Pitch 1: Four-Seam Fastball, RH pitcher

Let's use a pitcher who puts a 2000 rpm rate of revolution on the pitch at a 70 degree arm angle. This is how the pitch reacts to the air in comparison to the conditions described below.

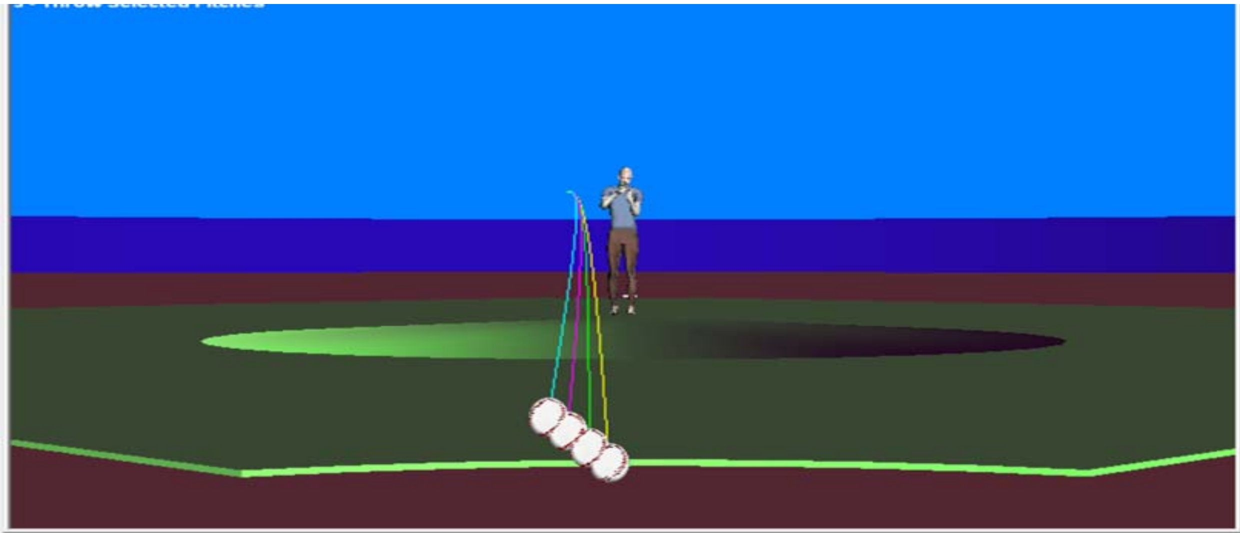
Pitch 2: We changed all parameters except speed & rpm

We changed the **elevation to sea level, the humidity to 20%, and the temperature to 60 degrees F**. NeeleyAir Gauge Reading = 70

Let's compare this pitch to the same pitch having changed the elevation to sea level such as San Francisco, the temperature to 60 degrees and the humidity to 20%.



This is the amount of adjustment the hitter must make in his muscle memory for the combined changes. Here is where the **visual memory** must match the muscle memory for the hitter to be successful. If the visual memory of the colder, sea level pitch is distant, say one or two weeks, then the hitter will most likely show difficulty hitting the four-seam fastball off a good pitcher until his memory of the visual is more recent, say one or two days and more similar to the home team. This is the basis for the **Visual Memory Index**.



A representation of several increments of fastball movement between the extremes of Colorado and sea level climates

For additional information, or to see a video of these physics demonstrations, contact Clifton Neeley
cliftonneeley@comcast.net or visit our website at www.baseballvmi.com

90 mph 4-seam Fastball additional hop or movement at sea level				
	30 deg. F Temp	60% RH	1000 feet Elevation	Combined ball movement differential At sea level
Lesser ball movement at 1,000 feet	1-1/2 inches	3/8 inch	3/4 inch	**= 2-5/8"** Add'l hop or lift + some slide for 70 or 80 deg. Arm slot.
	10 deg. F. Temp	20% RH	500 feet Elevation	Combined Differential
Lesser ball movement At 500 feet	1/2 inch	1/8 inch	3/8 inch	**= 1"** Add'l hop or lift + some slide for 70 or 80 deg. Arm slot.
	40 deg. F Temp.	60% RH	5,000 feet Elevation	Combined Differential
Lesser ball movement 5,000 feet	2 inches	3/8 inch	3-3/4" inches	**=6-1/8"** Add'l hop or lift + some slide for 70 or 80 deg. Arm slot.

