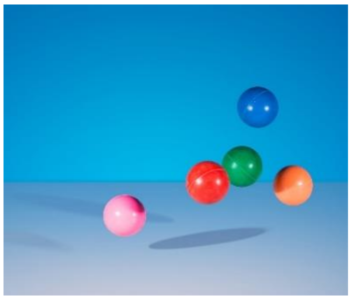
NPL

Measurement At Home

Report on Temperature Bounce



1. Overview

This report uses tests on 27 balls which were received in a few days of issuing this challenge. **Thank you:** Aleks, Caoimhe, Connor, Daanis (who sent a very extensive report), Daniel, Jenush, Manny, Rachel, Richard and Sas.

The overall finding was that balls bounce less after several hours in a freezer.

The reduction was between one third of original (sliotar) to a small increase (ping pong ball). Most balls bounced to about 2/3rd of their original height. Balls of the same type had similar reductions.

2. What was the measured effect (change in first bounce height)?

In this report we shall use FBH to mean 'first bounce height'.

The table here gives the size of the effect, which is the after-chilling FBH divided by before-chilling FBH.

Ball	Measured effect (FBH before-chill / FBH after-chill)	FBH before-chill (%)
Plastic	33	60
Sliotar (leather ball for hurling)	35	34
Tennis (mean of 5)	55 (44-128?!)	49 (44-56)
Foam (mean of 3)	65 (43-87)	39 (28-46)
Rubber (mean of 5)	67 (23-91)	71 (63-86)
Hard rubber	68	31
Jelly	74	78
Rubber eyeball	86	59
Golf (mean of 2)	91	75
Ping Pong (Mean of 2)	109	64

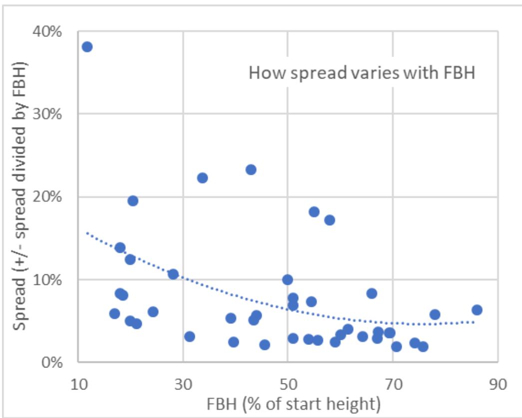
The plastic ball and sliotar were most affected by temperature – reducing FBH to a third of that before cooling.

Golf balls seem least affected by temperature - FBH was reduced to 90%.

One tennis ball and one ping pong ball bounced to 128% of original FBH. Although a bit suspicious of these results, we left them in the table.

3. How big was the spread of results, and how did it vary with FBH?

The plot here shows the spread in the 6 results for the balls at all temperatures, as a function of FBH. The dotted line is a simple curve fit.



Balls with higher FBH (above 60%) seem to have less spread in the results.

The biggest spread (and lowest FBH) was for the chilled sliotar.

A spread of about 8% of the value seems normal.

4. Conclusions and discussions

Cooling balls overnight in a freezer almost always reduces measured bounciness, though the amount varies with ball type. Balls can be categorised as hollow or non-hollow, with hollow balls containing differing types of cavity from one large cavity to thousands of tiny gas pockets. They can also be elastic or non-elastic (though only elastic balls were tested (e.g. none made of wood or stone). Combinations of these types occur, and other factors affect bounce such as gas pressure within cavities, elastic material, material composition and surface texture. The hardness and texture of the floor will also affect results. Floors or balls with rough surfaces might cause horizontal movement, which reduces the energy used in vertical motion.

The spread of results when testing a ball 6 times seems to vary with bounce height. The spread could be due to the surface finish or how it was dropped. If you look at the complicated surface of the sliotar, you can see why it had the greatest spread. It is always good practice to measure more than once (hence the saying in tailoring circles *"measure twice, cut once"*). If only one measurement had been made, a result could be up to 10% different to that provided by the mean or the average of 6. The spread described here is called 'peak to peak' spread as it involves the highest and the lowest value. The results from many measurements will tend to cluster close to the average giving a better result overall, so people have to decide how much effort they choose to put in to achieve a given level of uncertainty.

People got different results. The main reason for this was because they used different balls, the 'warm' temperatures were probably different, and they may have dropped them differently.

5. Overall comments

What makes balls bounce?

We thought of two main ways temperature changes vertical bounciness: **molecular bonds** and **gas pressure**. In all sport, balls also travel horizontally which means surface texture and friction also affect bounce height.

Rubber (and other elastic materials) comprise chains of molecules that bend, stretch and slide over each other. Cooling makes bonds between the molecules less springy and less slippery.

The amount of kinetic (motion) energy of particles in a gas changes with temperature. If the gas inside hollow (including foamy) balls has less energy (is cooler) than that of ambient air, the reduced pressure from within the ball makes it 'flatter' (in the way tyres become flat) which reduces bounce.

A comprehensive write up sent in by **Daanish** pointed out that in science, the ***coefficient of restitution*** describes how much energy is lost in collisions, which relates to bounce.

How important is ball bounce?

Sports people are very interested in bounce and allegedly use tricks, such as rubbing to warm them, to increase bounce. Different sports have various ideal bounce factors. We were very surprised at how bouncy golf balls are. Footballs are regularly re-inflated to keep them at the correct pressure and bounciness. Tennis players only use balls for a while before gas leaks make them too 'flat' to use. Air pressure within tennis balls *should* be about twice that of ambient. To keep this high pressure before the first use, pro tennis balls are sold in pressurised canisters that pop when opened.

In professional sport ***bounce meters*** are used to test balls. They often use a microphone to listen to time between bounces, and, assuming a particular value for acceleration due to gravity, evaluate bounce from how time reduces between successive bounces.

Spin?

Finally, balls can spin. We didn't mention that in this test the ball should not spin when dropped. Any spin could lead to the ball moving horizontally by an amount depending on the friction between the ball and landing surface, which in turn affects the vertical bounce level.

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