Comparing Barrett and Kawhi's Lucky Basketball Shots

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1 Introduction

On May 1, 2026, the Toronto Raptors were playing the Cleveland Cavaliers in the sixth game of their NBA basketball playoff series. The game went into overtime, and came down to the last few seconds, with the Raptors down by one point. Young Canadian star RJ Barrett shot a long three-point attempt [3]. If it scored, the Raptors would win the game and carry on. If it missed, they would lose and be eliminated from the playoffs. Barrett's shot was slightly long, and bounced off the far rim, high up in the air. After what seemed like an eternity, it came back down, and landed right in the hoop. Raptors win!

Toronto fans were immediately reminded of another event, seven years earlier, on May 12, 2019. Tied with the Philadelphia 76ers, in the final seconds of the seventh and deciding game of their playoff series. Kawhi Leonard dribbled to his right, and put up an awkward shot from the corner of the court [2]. This shot was slightly too short. It bounced off the near rim, nearly straight up. It then bounced off the same rim a second time. Then off to the far rim for two more bounces, before finally landing in the hoop. Raptors win again!

In both games, the Raptors played well, and showed a lot of talent and skill. But those two final shots also seemed kind of *lucky*. Were they? How much so? Which one was luckier? How can we measure such things? Or even *define* them?

It's clear enough that if those two shots had been a little bit *worse* – if Barrett's shot had been a little bit longer, or Kawhi's a bit shorter – then they would have missed, and the Raptors would have lost. But was that luck or skill? Perhaps it was their talent that kept the shot within range. It's difficult to distinguish luck from skill in such cases (e.g. [5, 1]).

But what is also true, is that if those shots had been a little bit *better*, i.e. *closer* to the middle of the hoop, then they also might have missed. And *that* seems like pure luck and nothing more. After all, surely both players were *trying* to aim for a "swish", whereby the ball lands right in the middle of the hoop. If being *farther* from a swish is what allowed them to score, then that wasn't due to skill, it was just good fortune.

Inspired by those considerations, and in the spirit of mathematical analysis of basketball issues (e.g. [4]), this paper sets out to answer the following question. How much *closer* to the center of the hoop would those two shots have had to be, so that once all of their bounces

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are taken into account, they would have missed instead of scoring? To answer that, we will have to think carefully about bounce angles, trigonometry, and gravity. We will eventually determine that if Barrett's shot had been just over one centimeter[2] (less than half an inch) closer to the center of the hoop, then it would have bounced short and failed to score. And, if Kawhi's shot had been just 1/17 of a centimeter closer, then its second bounce would have gone long on the other side of the rim, also missing.

So, yes, both shots were extremely lucky – Kawhi's even more so.

2 Preliminary Results about Bounces

To compute the various angles and distances involved with those shots, we need to derive some facts about the geometry of bounces.

To get started, suppose that an object (such as a ball) moves along a trajectory in a constant gravitational field, at an initial angle $\theta \in [0, \pi/2]$ from the horizonal, achieving a maximum altitude gain of $H > 0$, before eventually returning to its original altitude after a time $T > 0$, at a horizontal distance $L > 0$ away from its original position. Then we have the following relationship between H, L, and θ (see Figure 1):

Proposition 1 *If that same object had started in the same original position and velocity and angle, but in the absence of a gravitational field, then after the same time T, it would be at an altitude $4H$ and horizontal distance L from its original position. Hence, the angle θ from the horizontal satisfies* $\tan(\theta) = 4H/L$, *i.e.* $\theta = \arctan(4H/L)$.

Proof #1 (logical). Since gravity only affects vertical movement, the horizontal distance L is unaffected, and we need only consider the vertical. In the first half (time 0 to $T/2$) of the object's trajectory, its upward velocity value changes from some initial velocity $v_0 > 0$ to 0, in a linear fashion (due to the constant gravitational acceleration). Hence, on *average*, it moves at a velocity $v_0/2$. So, in time $T/2$, it moves a vertical distance $(v_0/2)(T/2) = v_0T/4$. The observed maximum altitude is therefore $H = v_0T/4$. By contrast, in the absence of gravity, its velocity v_0 would remain unchanged, so in time T it would instead move a vertical distance v_0T. By the above, $v_0T = 4H$, giving the result. ∎

[2]Reminder for American readers: one meter (m) is a slightly over three feet, and one centimeter (cm) is 1/100 of a meter, or about 40% or 2/5 of an inch.

Effect of Gravity on Trajectory

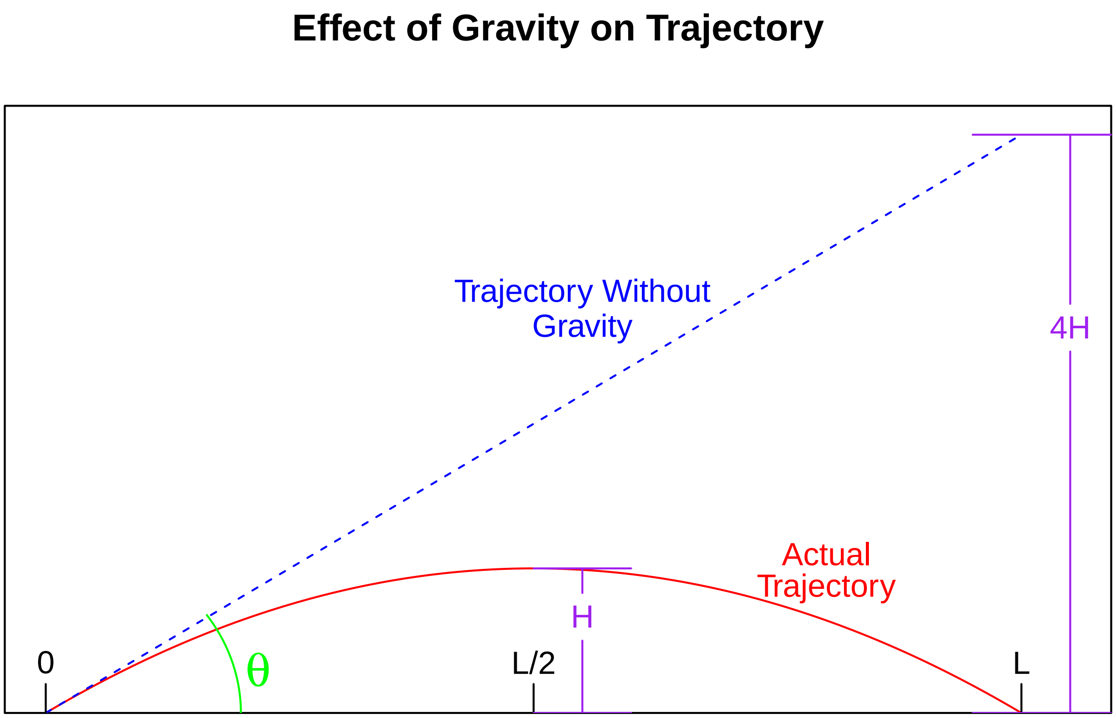

Figure 1: Illustration that in the absense of gravity, the object will reach four times the altitude H over the same time interval T and horizonal length L, so that $\tan(\theta) = 4H/L$.

Proof #2 (algebraic). Due to the constant gravity, the object follows a parabola. Consider a coordinate system in which the object begins at the origin, and reaches its maximum altitude $y = H$ when $x = L/2$, before returning to its original altitude when $y = 0$ and $x = L$. This trajectory satisfies the relation $y = H - (4H/L^2)[x - (L/2)]^2$. The tangent line has slope given by $y' = 2(4H/L^2)[x - (L/2)]$, which at x=0 is equal to $4H/L$. Hence, when this tangent line is extended out to x=L, the value of y there is equal to $(L)(4H/L) = 4H$. ■

Aside. Proposition 1 remains true regardless of the nature of the grativational field, as long as it is constant. So, it would also hold when playing basketball on Mars!

We next consider how the horizontal distance L depends on the angle.

Proposition 2 *If an object is launched in a constant gravitation field at an initial angle $\theta \in [0, \pi/2]$ from the horizonal, then keeping its initial force constant, the horizontal distance L traveled before returning to the same altitude is proportional to* $\sin(2\theta)$.

Proof. Due to the constant gravitational field, the time T until the object returns to the same altitude is proportional to $\sin(\theta)$. And, its horizontal velocity is proportional to

$\cos(\theta)$ and remains constant throughout its trajectory. Hence, the total horizontal distance traveled is proportional to $\sin(\theta)\cos(\theta)$. The result follows since $\sin(\theta)\cos(\theta) = \frac{1}{2}\sin(2\theta)$. ■

Aside. Proposition 2 shows that to throw an object as far as possible, you should throw it at a 45 degree angle to maximise $\sin(2\theta)$, since $\sin(2 \cdot 45°) = \sin(90°) = 1$.

One issue regarding Proposition 2 is that there can be two different plausible angles which give the same value of $\sin(2\theta)$. For example, if $\theta_1 = \pi/18$ radians (10 degrees), and $\theta_2 = 4\pi/9$ radians (80 degrees), then $\theta_1, \theta_2 \in (0, \pi/2)$, but $\sin(2\theta_1) = \sin(2\theta_2)$. This corresponds to two different ways to achieve the same total horizontal distance – a short hard trajectory or a high arc. When considering modified versions of shots below, we will usually choose the angle which is most similar to the previous version.

Aside. In Proposition 2, the maximum altitude H that the object reaches is actually proportional to $\sin^2(\theta)$, since it is the product of the time $T \propto \sin(\theta)$ and the initial vertical velocity $\propto \sin(\theta)$. But we do not use that fact here.

Simplification. If the angles θ all remain very close to $\pi/2$ (i.e. 90 degrees), so always $\sin(\theta) \approx 1$, and the trajectory's time T and maximal height H remain approximately constant, then to first order in Proposition 2, the horizontal distance L is proportional to just $\cos(\theta)$, which might sometimes seem simpler and more intuitive that $\sin(2\theta)$ (see below).

3 Analysis of Barrett's Shot

With the above results about bounces in hand, we can begin actual calculations. We begin with Barrett's shot. We require two additional constants. The radius of an NBA basketball is $R = 0.2286$ meters, or about 23 cm (9 inches). And the diameter of an NBA hoop is $D = 0.75$ meters (29.5 inches). Also, we note that Barrett's shot bounced up a huge amount, estimated in one video to be at least $H = 2.1$ meters. And, it traveled a horizontal distance from centered on the far rim to near the middle of the hoop, so $L \approx D/2 \doteq 0.375$.

In terms of these values, it follows from Proposition 1 above that the ball's initial angle with the horizontal upon bouncing off the far rim was equal to $\theta = \arctan(4H/L) = 1.526$ radians, or about 87.4 degrees (nearly vertical). How could the ball have achieved such an initial angle? It must be that when it hit the (far) rim, the center of the ball made that same angle with the rim. Hence, the center of the ball must have had initial horizontal distance $X = R\cos(1.526) \doteq 0.0102$ (about one centimeter, or 2/5 of an inch) from the rim.

So, how much closer to the center of the hoop (i.e., farther from that far rim) would the ball's center have to be, for it to instead bounce past the near rim and miss the shot? Well, the new horizontal distance $\widehat{L}$ would have to be at least equal to the rim diameter D, i.e. we would need $\widehat{L} > D = 0.75 \doteq 2L$. What initial position $\widehat{X}$ would achieve that?

Using the "Simplification" above (since the bounces were so high that the horizontal angles were all near 90 degrees), we would need $\cos(\widehat{\theta})/\cos(\theta) = \widehat{L}/L \doteq 2$. Since we know that $\theta = 1.526$, this means that $\cos(\widehat{\theta}) \doteq 2\cos(1.526) \doteq 0.0896$, whence $\widehat{\theta} = \arccos(0.0896) \doteq 1.4811$ or about 84.9 degrees. This slightly *smaller* angle from the horizontal would be achieved if the ball's initial horizontal distance from the far rim was instead $\widehat{X} = R\cos(1.4811) \doteq 0.02048$, or just over two centimeters. Hence, if Barrett's shot had hit that far rim just over one centimeter *closer* to the center of the hoop than it actually did, then it would have bounced out the front and missed, and the Raptors would have lost!

Or, using the full result from Proposition 2 above, we need $\sin(2\widehat{\theta})/\sin(2\theta) = \widehat{L}/L \doteq 2$, so $\sin(2\widehat{\theta}) \doteq 2\sin(2 * 1.526) \doteq 0.1789$. This allows that either $\widehat{\theta} = \arcsin(0.1789)/2 \doteq 0.0899$ or $\widehat{\theta} = (\pi - \arcsin(0.1789))/2 \doteq 1.4809$, i.e. either 5.2 or 84.9 degrees. Obviously the latter is most similar to θ, and is hence our choice. This implies that the ball's center's alternative horizontal distance from the rim would be $\widehat{X} = R\cos(1.4809) \doteq 0.02052$. As expected, the two approaches give virtually identical results: **If Barrett's shot had hit the far rim just over one centimeter closer to the hoop's middle, then it would have missed.**

So, Barrett's shot was very lucky indeed. But how does it compare to Kawhi's shot?

4 Analysis of Kawhi's Shot

We next turn to Kawhi Leonard's shot from 2019. It is somewhat more complicated than Barrett's. For one thing, the angles are not all near 90 degrees, so we can not use the above "Simplification". More importantly, Kawhi's shot bounced a total of *four* times on the rim before finally scoring. So, even figuring out the path it took (much less how it could be modified to miss) is non-trivial.

From direct video observation, Kawhi's shot progressed as follows. It first bounced about $H_1 = 0.8$ meters on the near side of the rim, then bounced about $H_2 = 0.3$ meters again on the near side, then crossed over to the far side of the rim and bounced about $H_3 = 0.2$ meters there, and then finally bounced about $H_4 = 0.1$ meters again on the far side, before finally landing inside hoop. We wish to track the actual locations and horizontal distances associated with each of these four bounces.

This task is challenging because the different bounces interact with each other. Making the second bounce larger (say) would change the location of the third bounce, which would then change the size of that third bounce. And, moving the second bounce's location (say) would change the distance to the third bounce's specified location, which would change our target for how large the second bounce should have been, etc. Consistency demands that the total horizontal distance L_i of the i'th bounce should correspond to the distance $X_{i+1} - X_i$ between the locations of the i'th and $(i+1)$'st bounces. To do this fit accurately, we work *backwards*, starting from the final (fourth) bounce and working back to the first bounce, doing some trial-and-error along the way to make everything fit, as follows (see Figure 2).

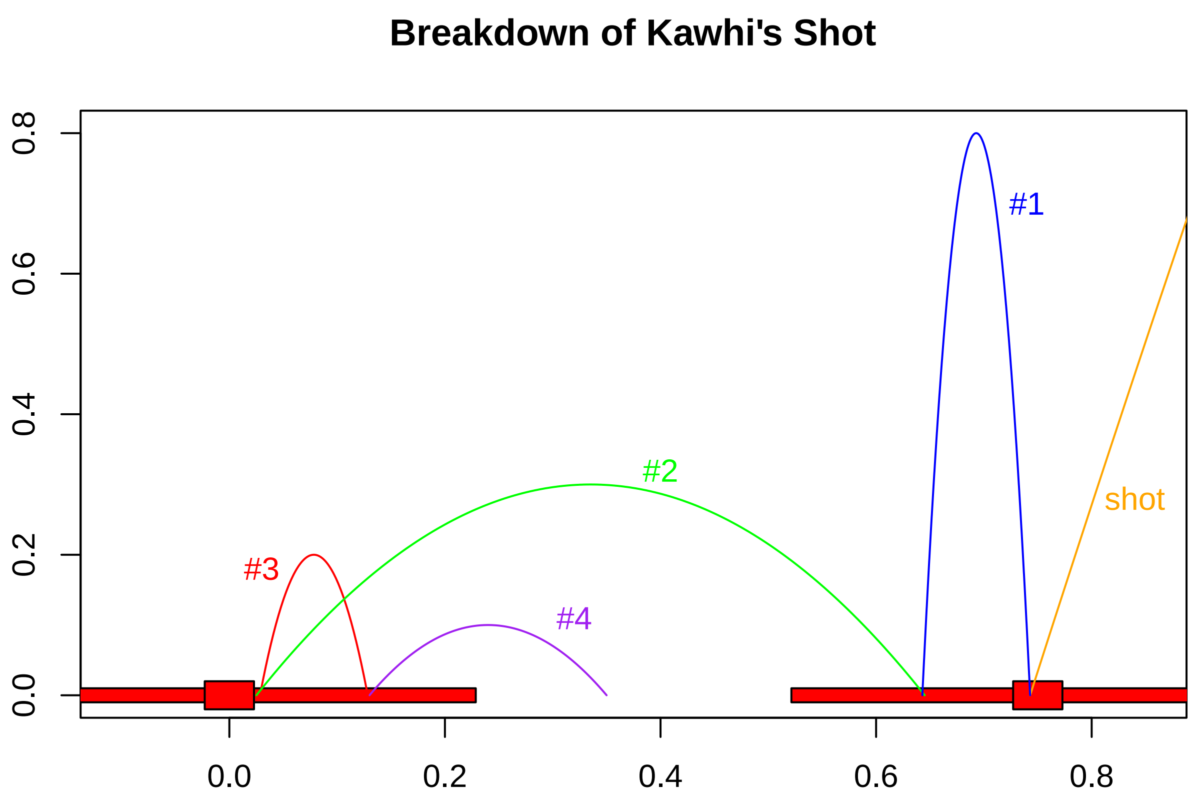

Figure 2: Diagram of the four bounces in Kawhi's famous shot. The curves follow the center of the ball. The rim edges (red) are drawn as wide as the ball, to indicate where the ball's center needs to land in order to score.

FOURTH BOUNCE: This bounce achieved roughly $H_4 = 0.1$ maximum altitude, and moved horizontally slightly more than one ball radius, roughly $L_4 \approx R + 0.05 \doteq 0.28$. So, by Proposition 1 above, the fourth bounce's initial angle with the horizontal was about $\theta_4 \approx \arctan(4H_4/L_4) = 0.9601$ (radians) $= 55.01$ degrees. It then follows from Proposition 2 that the position of the center of the ball at the start of the fourth bounce was about $X_4 \approx R\cos(0.9601) = 0.1311$ (meters), i.e. about 13 centimeters inside the far rim.

THIRD BOUNCE: This bounce achieved roughly $H_3 = 0.2$ maximum altitude, and moved horizontally approximately $L_3 \approx 0.1$. Hence, similar to the above, the third bounce's initial angle was about $\theta_3 \approx \arctan(4H_3/L_3) = 1.4464 = 82.87$ degrees, with horizontal position $X_3 \approx R\cos(1.3495) = 0.0284$. That is, the position of the center of the ball at the start of the third bounce was just under 3 centimeters inside the far rim. This is approximately consistent with the requirement that $L_3 \approx X_4 - X_3$.

SECOND BOUNCE: This bounce achieved roughly $H_2 = 0.3$ maximum altitude, and moved horizontally approximately $L_2 \approx D - 0.03 - 0.1 = 0.62$. So, its angle $\theta_2 \approx \arctan(4H_2/L_2) = 1.0939 = 62.7$ degrees. Hence, the horizontal position of its center from the near rim was about $X_2 \approx R\cos(1.0939) = 0.1049$, or just over 10 centimeters inside the near rim. In this case, since the second bounce crossed from the near to the far rim (distance D), with X_2 the distance inside the near rim and X_3 the distance inside the far rim, the consistency relationship is that $L_2 \approx D - X_3 - X_2$.

FIRST BOUNCE: This bounce achieved roughly $H_1 = 0.8$ maximum altitude, and moved horizontally approximately $L_1 \approx X_2 - 0.005 \doteq 0.10$. So, its angle $\theta_1 \approx \arctan(4H_1/L_1) = 1.5396 = 88.21$ degrees (nearly vertical). Hence, the horizontal position of its center from the near rim was about $X_1 = R\cos(1.5396) = 0.0071$, or less than one centimeter inside the near rim. Then we have the consistency $L_1 \approx X_2 - X_1$.

Now that we have (painstakingly) mapped out all four bounces of Kawhi's crazy shot (Figure 2), we can ask how this shot could have been even closer and yet failed to score. The simplest way would be for the first bounce to take it right over the far side of the rim. This would require that its new horizontal distance $\widehat{L}_1$ had $\widehat{L}_1 \approx D = 0.75$, so by Proposition 2 its new initial angle $\widehat{\theta}_1$ would have to satisfy that $\sin(2\widehat{\theta}_1) = \sin(2\theta_1) = \widehat{L}_1/L_1 \approx 0.75/0.1 = 7.5$. This means that $\sin(2\widehat{\theta}_1) = 7.5\sin(2\theta_1) = 7.5\sin(2 * 1.5292) \doteq 0.6232$, so $\widehat{\theta}_1 = \arcsin(0.6232)/2 \doteq 0.3364 = 19.28$ degrees.

This modification would give its new initial horizontal distance from the near rim as $\widehat{X_1} = R\cos(0.3364) = 0.2158$. Compared to the actual initial position X_1, this is nearly 21 centimeters closer to the center of the hoop. So, if Kawhi's shot had hit 21 centimeters closer to the center, then it would have bounced its center just past the far rim (on the first bounce), and then continued farther away and missed.

Now, 21 centimeters is still not too much – less than a foot. But it does represent a non-trivial modification of what actually happened. This raises the question, is there some way the shot could have missed while still being more similar to (but still better than) the original shot? Yes indeed – it is possible that the first bounce still landed on the near side of the rim, but slightly closer to the center, so that the *second* bounce would carry the ball over the far rim to still miss. What would be required for that?

Well, for the second bounce to extend beyond the far side of the rim, we would need $\widehat{L}_2 > L_2 + X_3 \doteq 0.62 + 0.03 = 0.65$. By Proposition 2, this could be achieved if $\sin(2\widehat{\theta}_2) = \sin(2\theta_2) = \widehat{L}_2/L_2 = 0.65/0.62 = 1.0484$. That would make $\sin(2\widehat{\theta}_2) = 1.0484\sin(2\theta_2) = 1.0484\sin(2*1.0939) \doteq 0.8551$. This allows for either $\widehat{\theta}_2 = \arcsin(0.8551)/2 \doteq 0.5129 = 29.4$ degrees, or $\widehat{\theta}_2 = (\pi - \arcsin(0.8551))/2 \doteq 1.0579 = 60.6$ degrees. Clearly, the second option is again closest to the actual second bounce, so we take that as our value of $\widehat{\theta}_2$. This means the second bounce would have to have been centered at the position $\widehat{X}_2 = R\cos(1.0579) = 0.1122$, or about 11.2 centimeters inside the near rim. This is about 0.75 cm farther than the actual second bounce position X_2.

The question then becomes, how could the first bounce be modified to achieve this new position $\widehat{X}_2$ for the second bounce. For that, we would need $\widehat{L}_1 > L_1 + 0.0075 \doteq 0.1075$. So, $\sin(2\widehat{\theta}_1) = \sin(2\theta_1) = \widehat{L}_1/L_1 = 0.1075/0.10 = 1.075$. This means that $\sin(2\widehat{\theta}_1) = 1.075\sin(2\theta_1) = 1.075\sin(2*1.5396) \doteq 0.06703$, and hence (again taking the second of two options for arcsin) that $\widehat{\theta}_1 = (\pi - \arcsin(0.06703))/2 \doteq 1.5373 = 88.08$ degrees. That in turn implies that $\widehat{X}_1 = R\cos(1.5373) = 0.0077$.

Compared to the original position $X_1 = 0.0071$, we see that the new position $\widehat{X}_1$ for the first bounce is only about 0.0006 m = 0.06 cm = (1/17) cm farther inside the near rim. That is sufficient to make the second bounce about 0.75 cm farther inside the near rim than it was, which would in turn push the third bounce to the outside of the far rim, leading to a missed shot. That is: **If Kawhi's shot had hit the near rim 1/17 of a centimeter closer to the hoop's middle, then it would have missed.**

Needless to say, 1/17 of a centimeter is an incredibly tiny distance, less than 1/40 of an inch. Kawhi was indeed very very lucky that his shot did not land 1/17 cm closer to the center of the hoop, since then it would not have scored a basket in the end. Phew!

5 Discussion

This paper has used simple geometry and analysis to determine how much closer (better) these two famous basketball shots would have had to be in order to miss. For Barrett's shot in 2026, it is just over one centimeter. For Kawhi's shot in 2019, it is even less, about 1/17 of a centimeter. So, both shots were very lucky indeed, and Kawhi's even more so.

The analysis herein, like most mathematical arguments about real-world phenomena, made various simplifying assumptions. Many possible physical influences on the ball's path were ignored, such as air resistence, ball spin and other pre-bounce properties, the ball's non-smooth surface, the positive thickness of the rim itself, the slight difference in altitude depending on the angle at which the ball hits the rim, etc. Plus, of course, the maximum altitudes of the various bounces were estimated from video observation, and are not completely accurate. In addition, the numerical calculations involved various approximations and are not 100% precise.

Nevertheless, I believe this analysis included the most important factors and influences on the ball's progress, and led to accurate estimates of how the ball's trajectory would be modified by slight changes in position and angle. I also hope that it points the way towards analysing other questions about real-world actions and effects, in sports and beyond.

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