David Alciatore, PhD ("Dr. Dave")

ILLUSTRATED PRINCIPLES

"Draw Shot Physics - Part I: basics"

***Note**: Supporting narrated video (NV) demonstrations, high-speed video (HSV) clips, and technical proofs (TP), and all of my past articles, can be accessed and viewed online at **billiards.colostate.edu**. The reference numbers used in the article help you locate the resources on the website. If you have a slow or inconvenient Internet connection, you might want to view the resources from a CD-ROM or DVD. Details can be found online at: **dr-dave-billiards.com**.*

Different people have different personal "Holy Grails" in pool. Most covet accurate aim and alignment, and an accurate and consistent stroke. Many people want (or should want) perfect speed control. Mastery of the draw shot is also on many people's list. The draw shot is an elusive skill for many novice players, and intermediate and advanced players constantly strive to improve control and power. I actually already wrote and entire series of articles on the draw shot (see my January '06 through July '06 articles). The focus of that series was on providing basic technique advice, presenting drills for improving your draw stroke, and predicting CB direction for draw shots with a cut angle. In this series, we will delve more into the physics of draw shots to better understand the best approach in different situations. For general advice on how to improve your draw shot technique, refer to my May '06 article and articles, advice, and drills under "draw" the FAQ section of my website.

First, let's review some basics and terminology. **Diagram 1** shows how tip contact point, tip offset, and cue elevation relate to each other. The **tip contact point** (see Diagram 1b) is where the cue tip comes into contact with the cue ball (CB). The **tip offset** (see Diagram 1b) is the distance between the line of action of the cue (through the contact point) and the center of the CB. Notice that when the cue is elevated (see Diagram 1d), the tip offset is still defined the same way. Obviously, with a draw shot, where the CB comes back toward the shooter, you need to hit below the center of the ball to give the CB backspin. However, if you use too much tip offset, or if your tip is not properly chalked, a miscue can result (see **NV 2.1** and **HSV 2.1**). The **miscue limit** (see Diagram 1a) refers to the maximum safe tip offset to avoid miscuing. The limit is generally accepted to be at half the ball radius (0.5 R). It just so happens that most ball manufacturers use a radius-wide stripe on balls 9 through 15, so you can use a striped ball when practicing "how low you can go" (see Diagram 1a). Many people designate the amount of tip offset (when applying English, draw, or follow) with a number of "tips." However, my January '08 and July '06 articles explain and illustrate why "tips of English," which depends on **shaft size** and **tip radius** (see Diagram 1c), can be confusing and misleading. I prefer to use a percentage instead. If the tip offset is at the miscue limit (half the ball radius), that is 100% tip offset (or English). If the tip offset is halfway to the miscue limit (one quarter the ball radius), that is 50% tip offset (or English). In Diagram 1c, I illustrate 80% tip offset as another example. Notice how subtle the difference is between 80% and 100%.

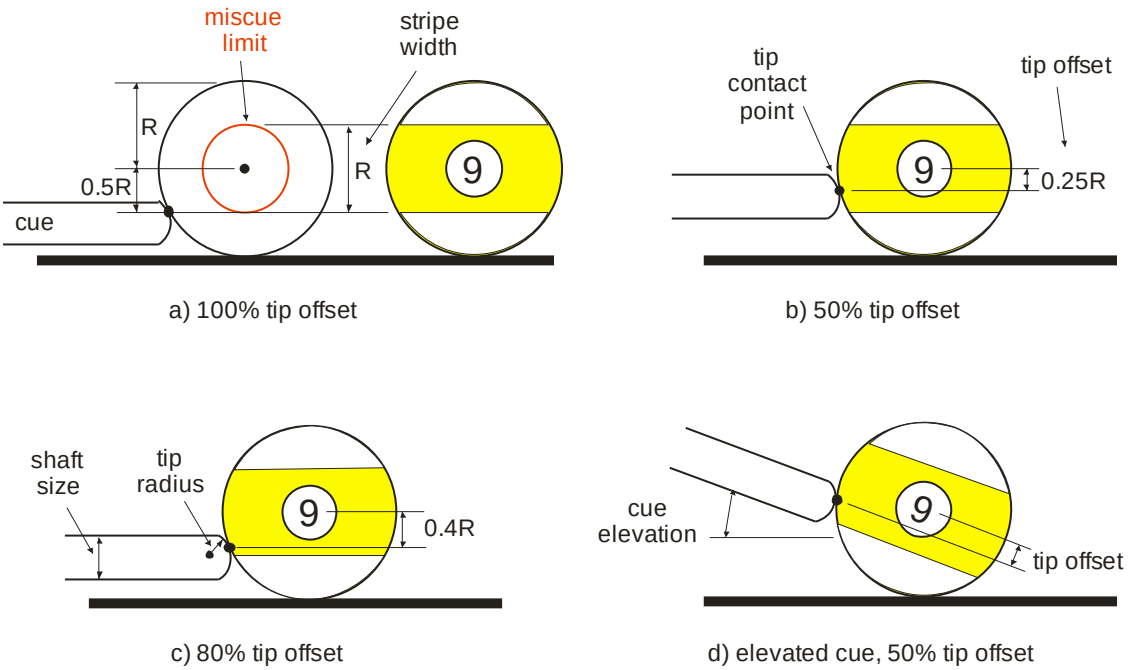

Diagram 1 Tip offset and miscue limit

normal video **NV 2.1** – Miscue due to off-center hit with no chalk

high-speed video **HSV 2.1** – Miscue due to off-center hit with no chalk

Diagram 2 shows the various phases that occur during a draw shot. The cue strikes the **cue ball (CB)** with a certain **cue speed** and **tip offset**. This gives the CB **forward speed** (CB speed 1) and **backspin** (CB spin 1). For a center-ball hit (i.e., no tip offset), the ball speed would be about 30%-40% greater than the cue speed, because the cue is about 3-times heavier than the CB (see **TP B.8**). As the tip offset is increased, more of the cue's energy goes into providing CB backspin. As a result, CB forward speed (CB speed 1) will be less at greater tip offsets. The CB slides across the cloth over the **drag distance** to the **object ball (OB)**. Over this distance, some of the forward speed and backspin wears off due to friction between the ball and cloth (see **HSV 3.1** and **NV B.10**). At contact with the OB, the CB has a slower speed (CB speed 2) and less backspin (CB spin 2). With a slower initial CB speed, more of the backspin and speed would be lost during drag, because the sliding friction has more time to "do its thing." Because the CB and OB are usually the same weight, and very efficient in collision, nearly all of the CB forward speed (CB speed 2) is delivered to the OB (OB speed 2), and the CB momentarily stops in place (see Diagram 2b). Because there is some friction between the balls, some of the CB backspin is lost during the collision (CB spin 3 < CB spin 2). After the collision, the OB moves away at nearly the approach speed of the CB (OB speed 2 = CB speed 2) and the CB remains spinning in place momentarily. This spin is called **overspin**, because the CB is spinning but not moving forward as fast as the spin wants it to. The overspin causes the CB to accelerate (i.e., develop forward speed) as the spin wears off some. When the CB speed and spin balance (i.e., there is no longer any sliding at the bottom of the ball), the CB has developed complete roll. In the diagram, sliding takes place over the **skid distance**. For "slicker" cloth, this skid distance will be longer (i.e., it

takes longer and farther for the draw to "take"). But regardless of how "slick" or "sticky" the ball and cloth are, the CB will have the same speed (CB speed 4) after the skid phase (see **TP 4.1**). Now the CB gradually slows to a stop due to what is called "rolling resistance." If a cloth is "fast," there is less rolling resistance, and the CB rolls a longer distance (**roll distance**). The total distance the CB draws back (**total draw distance**) is the sum of the skid distance and the roll distance ("total draw distance" = "skid distance" + "roll distance"). It is easier to draw the CB on a slick and fast cloth because there will be less drag (and less spin loss), the CB will skid farther with the post-collision overspin, and the CB will roll farther because of less rolling resistance.

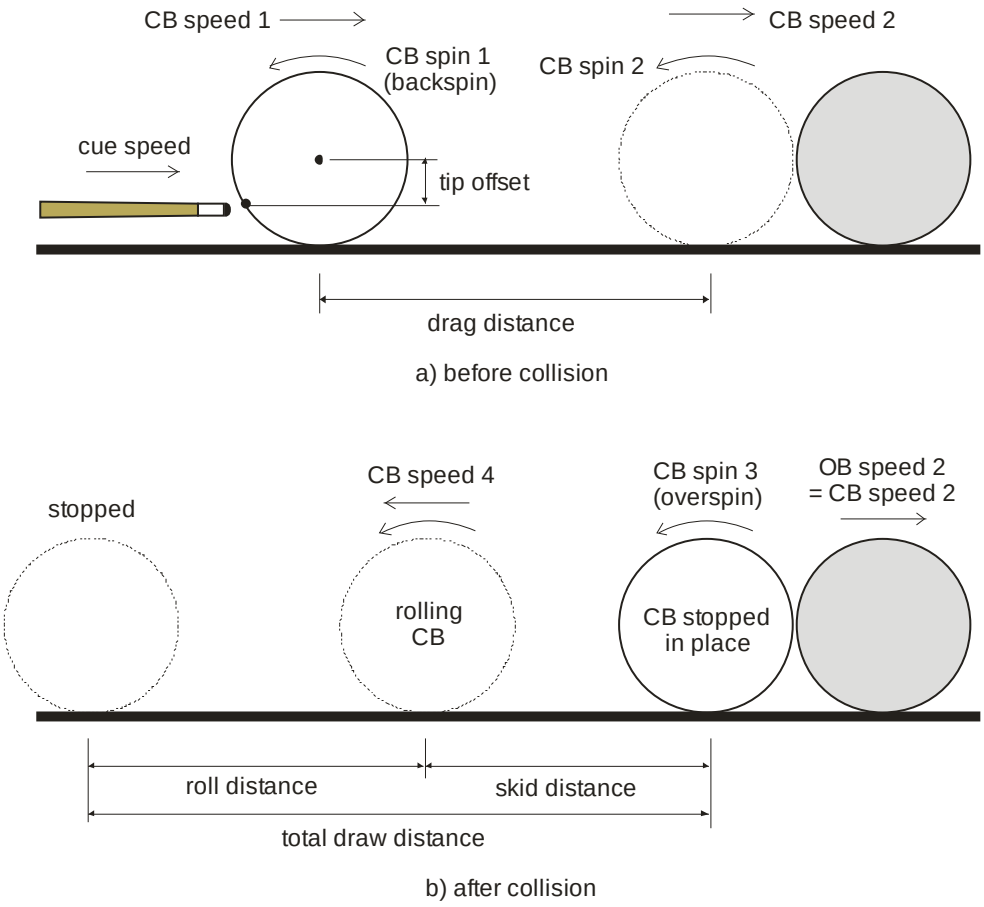

Diagram 2 Draw shot physics

high-speed video

HSV 3.1 – Stop-shot showing loss of bottom spin over distance

normal video

NV B.10 – Drag spin loss and English persistence

technical proof

TP B.8 – Draw shot physics
TP 4.1 – Distance required for stun and normal roll to develop

I have done a complete and thorough analysis of all of the physics involved with Diagram 2. All of the gory details, including lots of interesting graphs, can be found in **TP B.8**. Most pool players won't be very interested in all of the analysis, but many should be interested in the results. Here are the conclusions from the analysis:

1. Generally, **to get more draw**, you must **hit the cue ball harder** and lower. No big surprise here!
2. More tip offset does not produce significantly more draw as you approach the miscue limit; so, generally, **it is advisable to not hit too close to the miscue limit**.
3. With larger drag distances, and for a given maximum cue speed, **max draw occurs at less than maximum tip offset** (at about 70%-80% tip offset). In other words, you don't get more power draw by hitting closer to the miscue limit. But as illustrated in Diagram 1a and 1c, 80% is still fairly close to the miscue limit.
4. In general, with a draw shot with a medium desired draw distance, a **slower cue speed with more tip offset** will result in **better draw distance control** than a faster cue speed with less offset.
5. Stop shots are much less sensitive to tip offset position than draw shots are. In other words, **CB position is much easier to control with a stop shot**, as compared to a draw shot.
6. For a **short stop shot**, **slower speed** offers slightly better control. For **longer stop shots**, **faster speed** appears to offer slightly better control.
7. For **stun-through** (small controlled follow) and **stun-back** (small controlled draw), a firmer hit **closer to center** offers better CB control.
8. It is much **easier to control draw** distance **on a new, slick cloth** than it is on a "sticky" cloth, especially with lower-speed shots. The statement assumes the player is equally well "adjusted" to each cloth condition. Any player will need to adjust when playing under different cloth conditions.
9. It is **easier to draw the ball on slick cloth**, and **faster cloth allows for greater draw distances**.

Next month, we will look at some of the analysis results and conclusions in more detail. I want to thank all of the users on the BD-CCB and AZB online forums. They created excellent discussion and debate when I first posted the results on my analysis. I also want to thank Tom Ross, Dave Gross, and Bob Jewett for spending time with me on the phone sharing their thoughts and perspectives on various types of shots. Their advice, insights, and ideas helped shape my analysis and validate many of the conclusions.

Diagram 3 shows various types of shots resulting from different cue speeds and tip offsets. The names commonly used for each type of shot are also included. Take a look at all of the shots in the diagram and see how tip offset and cue speed create a wide range of CB and OB motion. The 1-ball "power draw" shot, where the CB is far from the OB, and we wish to draw the CB back a significant distance, both fast cue speed and large tip offset are required; however, as pointed out in conclusion 3 above, better success is achieved by backing away from the miscue limit slightly. With the 2-ball "draw shot," conclusion 4 suggests more tip offset and less speed offers better draw distance control. The 4-ball and 5-ball stop shots show how you can achieve the same CB action with radically different tip offsets and cue speeds. In this case, the different speed affects only how far the OB travels. Conclusion 7 suggests that the 3-ball and 6-ball "drag draw" and "roll through" shots are easier to control with more speed and less tip offset, as shown. The 7-ball "drag follow" shot shows what causes confusion for some novice players. They think: "If I hit below the center of the CB, the CB will draw back ... right?" Wrong, in this case. With the slower speed, the drag (sliding friction) action of the cloth removes all backspin and causes the CB to roll before reaching the 7-ball. The result is follow. A "drag follow" shot might be used

instead of a slower “roll shot” (similar to the 8-ball shot) if the table is not level or has an abused cloth. For a desired OB speed, faster speed can be used with the “drag follow” shot (since the ball slows during the drag) to help limit “roll off” (CB curving) due to non-ideal table conditions.

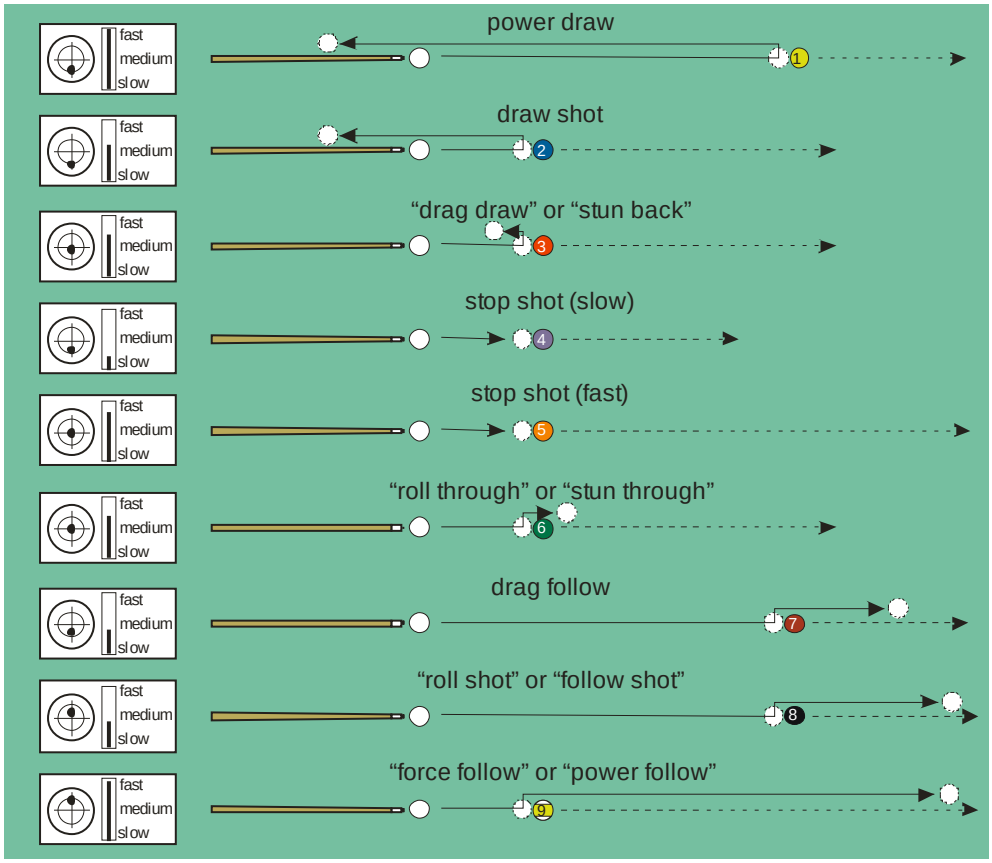

Diagram 3 Various named shots for different speeds and tip offsets

There is a good drill you can use to help you develop and improve your “feel” for the various shots in Diagram 3 (see the stop/follow/draw drill in the “Instructor and Student Resources” section of my website). The only way to develop consistency is to practice; so when you are done reading this article, go to a pool table and give me 20 (from Drill Sgt. Dr. Dave)!

Well, I hope you look forward to the remainder of my series of articles dealing with the draw shot. In future months, we will look at more details and examples for the conclusions above, the effects of cue elevation, and cut angle considerations.

Good luck with your game,
Dr. Dave

PS:

- If you want to refer to any of my previous articles and resources, you can access them online at ***billiards.colostate.edu***.
- I know other authors and I tend to use lots of terminology (e.g., squirt, throw, stun, impact line, etc.), and I know not all readers are totally familiar with these terms. If you ever

come across a word or phrase you don't fully understand, please refer to the online glossary on my website.

Dr. Dave is a mechanical engineering professor at Colorado State University in Fort Collins, CO. He is also author of the book, DVD, and CD-ROM: "The Illustrated Principles of Pool and Billiards," and the DVD: "High-speed Video Magic."