David Alciatore ("Dr. Dave") **ILLUSTRATED PRINCIPLES**

"Draw Shot Primer – *Part I: physics*"

***Note**: Supporting narrated video (NV) demonstrations, high-speed video (HSV) clips, and technical proofs (TP) can be accessed and viewed online at **billiards.colostate.edu**. The reference numbers used in the article (e.g., **NV 3.8**) help you locate the resources on the website. If you have a slow or inconvenient Internet connection, you might want to view the resources offline using a CD-ROM. See the website for details.*

Over the next few months, I will be presenting a series of articles dealing with draw shot principles. The goal is for the reader to come away with some useful information and systems for becoming more effective at planning and executing draw shots. In my January-July, 2004 articles (available on my website), I showed how the 90° and 30° rules are extremely useful tools in planning stun and follow shots. Therefore, the natural question is: "Well, what about draw shots ... is there a similar rule for them?" Well, let's start by exploring some basic physics so we can try to come away with some useful tools.

Unlike with the 30° rule for a natural roll follow shot, where the cue ball deflects close to 30° over a wide range of cut angles (see **NV 3.8** and my past articles), the deflected angle for a draw shot varies quite a bit as the cut angle changes. The physics and math details to show this can be found in **TP A.20**, and the results, which are probably more interesting to most people, are shown in **Diagram 1**. The graph shows how much the cue ball deflects away from its original direction for various ball-hit fractions. **Diagram 2** illustrates the deflected angle for 1/4-ball, 1/2-ball, and 3/4-ball hits. The cue ball's final path is deflected away from its original direction (the aiming line) by 58° for the 1/4 ball hit, 90° for the 1/2-ball hit, and 128° for a 3/4-ball hit. As you can see, the deflected angle varies significantly as the ball-hit fraction (cut angle) changes. That's one thing that can make draw shot position play challenging. However, as we will see next month, there are still some systems that will help you predict the final direction fairly reliably.

normal video

NV 3.8 – Using your hand to visualize the 30° rule

technical proof

TP A.20 – The effect of spin, speed, and cut angle on draw shots

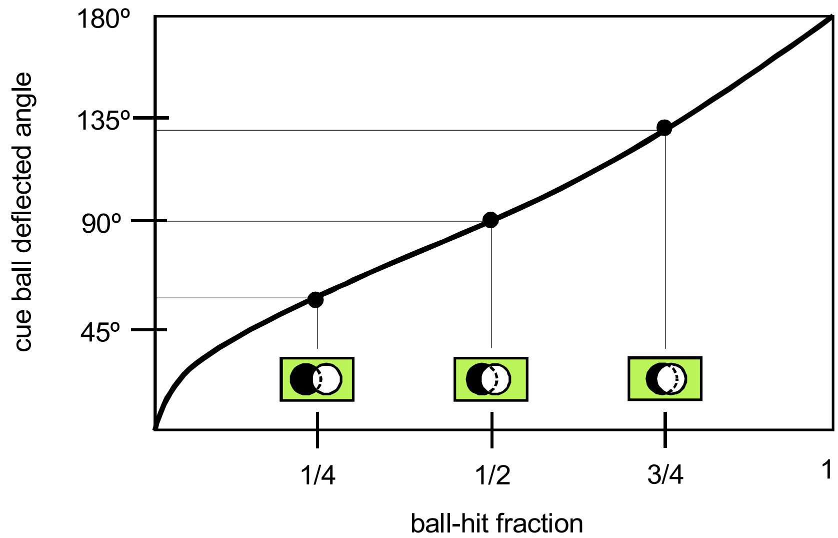


Diagram 1 Cue ball deflected angle vs. ball-hit fraction for an average draw shot

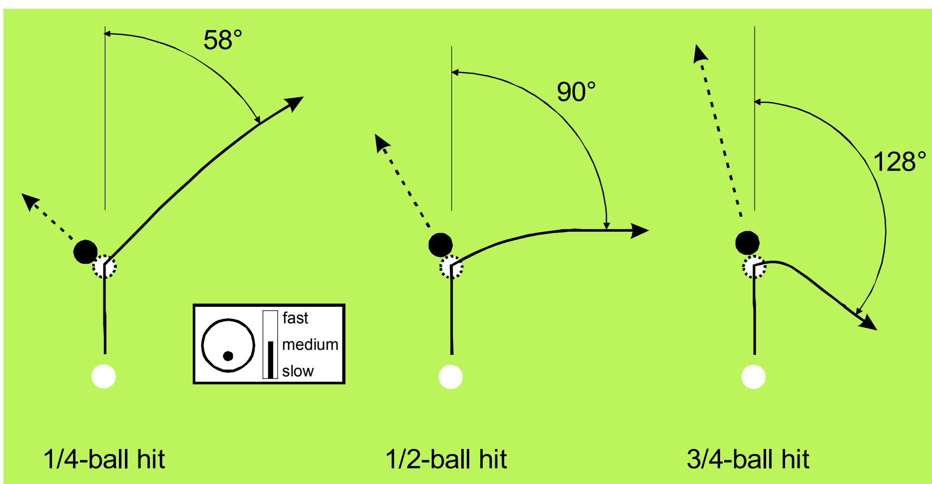


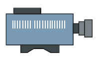
Diagram 2 Shots corresponding to the points in Diagram 1

Diagrams 1 and 2 reveal a useful principle (see **Principle 27**). For an average amount of draw, and for a 1/2-ball hit, the cue ball deflects by 90° (i.e., the final cue ball path is perpendicular to the original aiming line direction). As has been pointed out in this magazine before (e.g., see Bob Jewett's November, 2000 article), this is a very useful reference to have when trying to predict and plan cue ball motion for a draw shot.

Principle 27 Half-ball hit draw shot

The cue ball deflects 90° for a half-ball hit with an average amount of draw.

So what is an "average" amount of draw? Well, this is a complicated question, because the amount of cue ball backspin at impact with the object ball, which determines the amount of draw, depends on cue tip offset (how far off center you hit the cue ball), stroke speed, condition of the cue ball and cloth, and distance between the cue ball and the object ball. As shown in **HSV 3.1**, backspin wears off with distance, especially for slower speed shots. Here's the best answer for what is "average": It is the amount that results in 90° of deflection for a 1/2-ball hit. I know this might sound like a circular definition (based on **Principle 27**), but it offers a good way to calibrate yourself for shots of various distance and speed. Just hit a set of 1/2-ball hit shots at various speeds and distances to get a feel for how much cue tip offset creates the perpendicular cue ball deflection. Then you will have a feel for "average" draw. If you want a more technical answer to what "average" is, see TP A.20 and **TP A.12**. "Average" draw corresponds to a spin rate factor of 0.625. This means the rate of cue ball backspin, at impact with the object ball, is 62.5% of the natural roll rate of the cue ball (see TP A.12 for more information).


high-speed video

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


technical proof

TP A.12 – The relationship between cue ball spin cue tip offset

Diagram 3 shows what happens when you have less or more draw than "average." The blue (top) curve has 25% less spin than "average," and the cue ball does not draw as much (i.e., the deflected angle is less than 90°). The red (bottom) curve has 25% more spin than "average," and the cue ball draws more than "average" (i.e., the deflected angle is more than 90°).

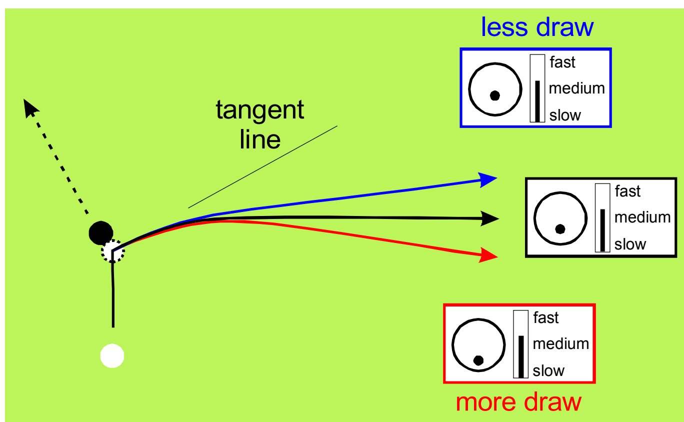


Diagram 3 Spin effects

Another factor to consider when predicting the final cue ball path for a draw shot is ball speed. **Diagram 4** shows the effect. As the speed is increased, the path follows the tangent line longer before deflecting to the final cue ball direction (e.g., see **NV 4.21**). This effect is summarized in **Principle 28**. In Diagram 4, all three shots have the same amount of draw action (i.e., the spin rate factor is the same for all three shots). To achieve this, the cue ball must be struck lower for the slower speed shot. This is because a larger percentage of the backspin wears off for a slower speed shot as the ball slides across the cloth to the object ball (e.g., see HSV 3.1). In Diagram 4, note how the deflected angle of the cue ball is 90° (i.e., the final path is perpendicular to the original aiming line direction) for all three speeds. This is because the spin rate factor (i.e., the amount of draw), at object ball impact, is the same for all three shots.

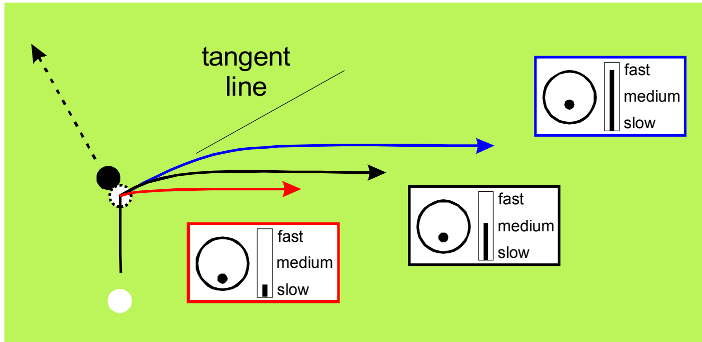


Diagram 4 Speed effects

NV 4.21 – Delay of draw and tangent-line deviation with higher speed

Principle 28 Draw shot tangent line persistence

The faster you hit a draw shot, the longer the cue ball travels along the tangent line before it curves to the final deflected angle.

Well, that's enough for the basics of draw shot physics. Next month, we'll look at how some of these results can be used to analyze and compare draw shot aiming systems.

Good luck with your game,
Dr. Dave

PS:

- If you want to refer back to any of my previous articles and resources, you can access them online at ***billiards.colostate.edu***.

Dr. Dave is a mechanical engineering professor at Colorado State University in Fort Collins, CO. He is also author of the book: "The Illustrated Principles of Pool and Billiards."