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

"Coriolis was brilliant ... but he didn't have a high-speed camera – *Part VI: maximum rolling deflection*"

***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.*

This is the sixth and final article in a series I am writing about the pool physics book written in 1835 by the famous mathematician and physicists Coriolis. Over the past five months, I described some high-speed camera work I've done and showed some examples that relate to some of Coriolis' conclusions. In the last three months, I presented principles dealing with the shape of the cue ball's path after hitting an object ball, the effect of spin and speed, the technique required to achieve maximum English, and the system Coriolis developed for aiming massé shots. FYI, all of my past articles can be viewed on my website in the Instructional Articles section. This month, I look at Coriolis' conclusion concerning cue ball deflection angle for natural roll shots, where the cue ball is rolling (i.e., not skidding or sliding) when it hits the object ball.

Diagram 1 illustrates the cut angle and deflected cue ball angle for various ball-hit fractions. If you are unfamiliar with these terms, you should spend some time studying the diagram. **Principle 26** summarizes Coriolis' conclusion, which states that for a rolling cue ball, the final deflected angle of the cue ball is largest (about 34°) for a cut angle slightly smaller than a half-ball hit. People sometimes assume that the maximum deflection occurs exactly at a half-ball hit; but if you want to be precise, it occurs at a cut angle of 28.1°, which corresponds to a ball-hit fraction of 0.53, instead of 30°, which corresponds to a ball-hit fraction of 0.5. (This is hardly enough of a difference for most people to care about; but Coriolis was a brilliant mathematician and physicist, and precision was important to him). The deflected cue ball angles (33.67° for a 1/2-ball hit vs. 33.75° for a 0.53-ball hit) are even less different than the cut angles, and it is practically impossible for a person to detect this difference (without accurate measuring instruments). If you want to see where all of the numbers come from, and if you like math and physics, check out **TP 3.3** and **TP A.4**. There, you can find complete derivations and interesting plots of the results.

<u>Principle 26</u> Coriolis' *maximum rolling deflection*

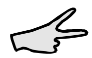
For a cue ball with natural roll, the largest deflection angle the cue ball can experience after impact with an object ball is 33.7°, which occurs at a cut angle of 28.1°.


technical proof

TP 3.3 – 30° rule
TP A.4 - Post-impact cue ball trajectory for any cut angle, speed, and spin

Diagram 1 shows the cut angles and cue ball deflection angles for 1/4-ball, 1/2-ball, and 3/4-ball hits. Notice that the cut angle is very different for these three shots, but the cue ball deflected angle is fairly close to 30° over the entire range. This is the basis of the 30° rule. If you have read any of my articles in the past, you know I have written a lot about this very useful principle. My April '04 article presented the basics, my May '04 and June '04 articles showed various applications and examples, and my February '05 through June '05 articles looked at various effects (e.g., speed, friction, elasticity, and English) in more detail. For demonstrations of the 30° rule and a half-ball hit, see **NV 3.8** through **3.10**, **NV 4.24**, and **NV 7.4**. **NV 3.8** is particularly useful because it shows how you can use your hand to visualize the 30° direction. Here's a useful poem to help you remember and apply the 30° rule:

If you let one finder stay,
The other finger points the way.
Peace.



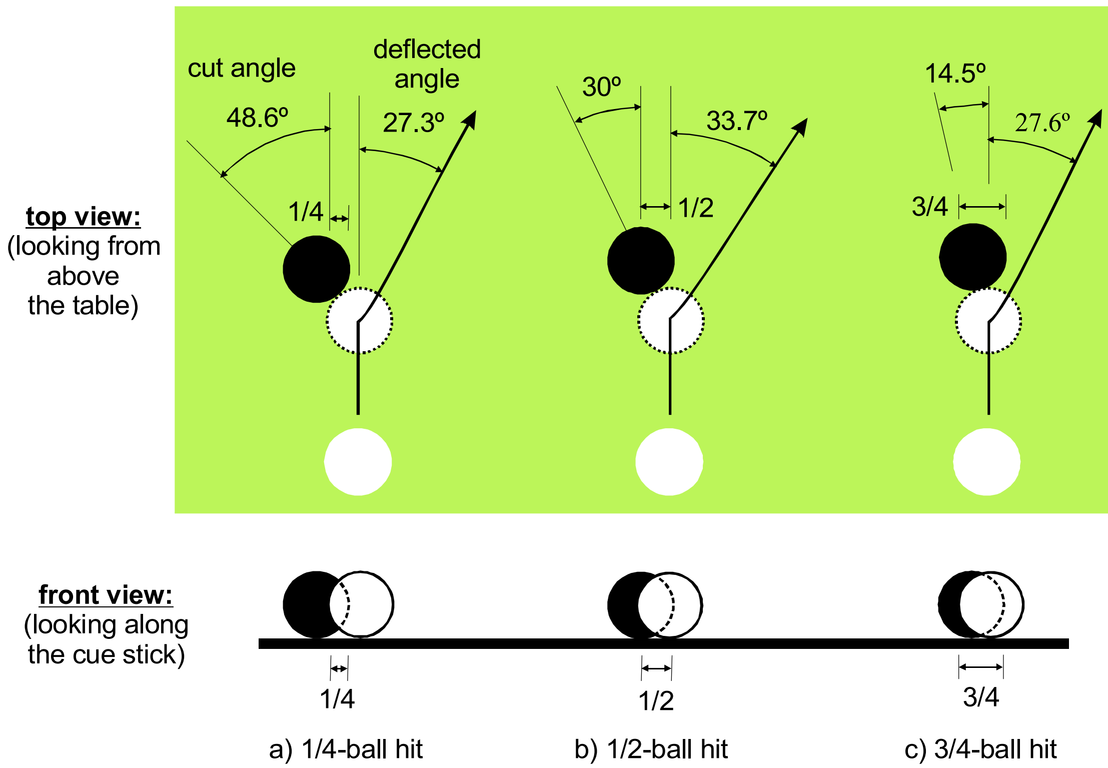


Diagram 1 Cut angles and cue ball deflection angles for various ball-hit fractions

normal video

NV 3.8 – Using your hand to visualize the 30° rule
NV 3.9 – 30° rule example
NV 3.10 – Using the 30° rule to check for and prevent a scratch
NV 4.24 – 30° rule speed effects
NV 7.4 – 30° rule billiard shot

So how can **Principle 26** be useful in practice? Well, knowing that the cue ball will deflect at an angle slightly larger for shots close to a 1/2-ball hit might help when you are using the 30° rule to avoid scratches, aim carom shots, plan break-up and avoidance shots, and get through traffic during position play (see my April '04 through June '04 articles for examples). Remember, the 30° rule isn't perfect over the entire range of ball-hit fractions. The deflected angle is a little larger close to a 1/2-ball hit (and even a little larger for a 0.53-ball hit), and it is smaller for cut angles closer to a 1/4-ball hit (i.e., a thinner hit) or a 3/4-ball hit (a thicker hit). So if you are using your peace-sign hand (see **NV 3.8**), stretch those fingers a little (to slightly widen the angle) for shots close to a 1/2-ball hit, and relax them a little (to slightly shorten the angle) for shots closer to a 1/4-ball hit or 3/4-ball hit. **Diagram 2** shows an example where you need to be aware of the subtle differences in the final cue ball direction. A run-out might be difficult in this situation due to the 5-ball-6-ball cluster. There also aren't any easy-to-execute safety opportunities. A carom shot, where you deflect the cue ball off the 1-ball into the 9-ball, is most definitely the best alternative with this table layout. Whenever I see 30° rule carom opportunities like this at the table, I salivate (like Pavlov's dog). I just pull out my trusty (and well calibrated) peace-sign hand and rejoice with delight if my index or middle finger happens to point to the target. As shown in my June '04 article, if the shot is aligned well, you have a huge margin of error (i.e., the shot is tough to miss). Unfortunately, the shot in **Diagram 2** is not lined up perfectly in the 30° direction. But this is where **Principle 26** comes into play. The required carom angle is a little larger than 30°, so we want to hit the shot as close to a 1/2-ball hit (or 0.53-ball hit) as possible to ensure enough cue ball deflection. It is a good idea to practice with your peace-sign hand to know how much to stretch your fingers to be able to predict the direction of the slightly larger angle. As described and illustrated in my June '05 article, you can also use speed to adjust the cue ball's path (by offsetting it along the tangent line), before it turns to the final deflected angle direction (see **NV 4.24**). This can come in handy if the deflected angle alone, at slow speed, doesn't quite get you to the target.

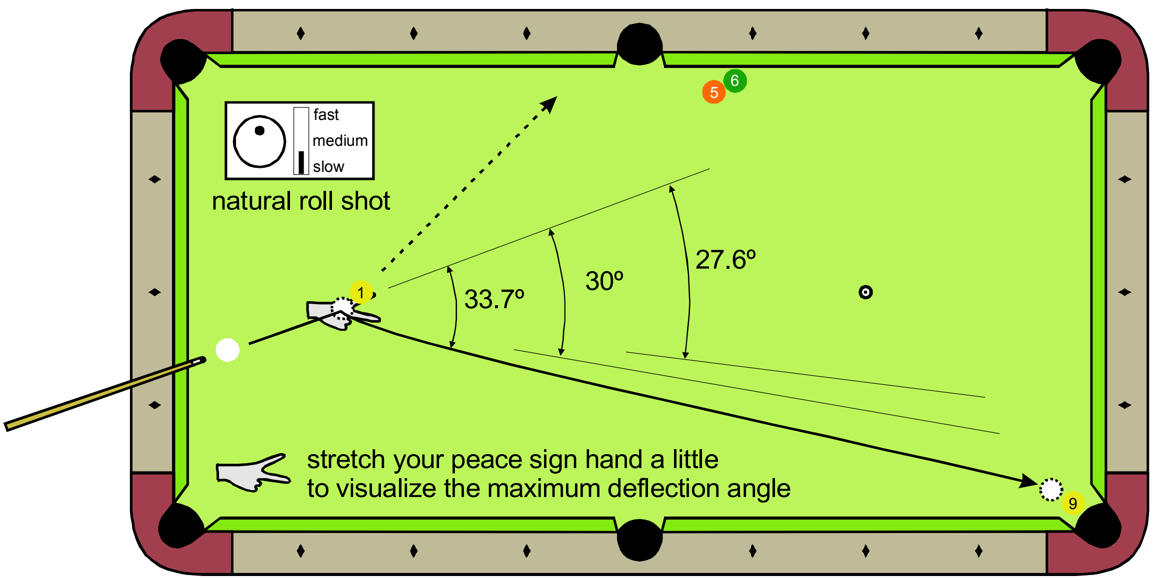


Diagram 2 Example where the maximum cue ball deflection is perfect

I hope you have enjoyed my series of articles about the work of Coriolis. Next month, we'll look at how to predict cue ball motion for various types of draw shots.

Good luck with your game, and practice hard,
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" (2004, Sterling Publishing).