David Alciatore, PhD (“Dr. Dave”) ILLUSTRATED PRINCIPLES

“Coriolis was brilliant ... but he didn’t have a high-speed camera – *Part I: Introduction*”

***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 4.20**) help you locate the resources on the website. You might also want to view the resources from a CD-ROM. See the website for more details.*

After writing twelve articles on the 90° and 30° rules, I’ve decided to move on to a new topic. For the next few articles, I will be summarizing and discussing results from a little known but amazing book on the physics of pool. The book’s title is Theorie mathematique des effets du jeu de billard (“Mathematical Theory of the Game of Billiards”**)**. It was written by the late, great Gaspard Gustave de Coriolis in 1835. Coriolis was a brilliant mathematician and physicist who is credited with discovering the “Coriolis” force. This is the force that causes hurricanes and tornadoes to turn counterclockwise in the northern hemisphere. It is also the cause of significant loads in the bearings of engines in moving vehicles (cars, planes, boats). Coriolis’ billiards book is THE BIBLE of pool physics! It covers pretty much every important pool physics relation that has ever been presented since. Unfortunately, it is not very widely read because it was written in French, and most of us can’t read that silly language. The book was never translated to and distributed in English. Also, Coriolis’ mathematics and complicated illustrations are difficult to follow by today’s standards.

Fortunately, David Nadler, a cue sports enthusiast who got a PhD in mathematics from Berkeyley in 1979, has recently been working on an English translation. The translation is not available yet – it is due out later this year. It will be announced on the Billiard Digest CCB online discussion forum when it comes out. Several months ago, David asked me to review his working draft. I was very happy to oblige because I’ve been really looking forward to reading Coriolis’ work. When I read the entire work, I was totally amazed by how much he had done so long ago (1835!). Coriolis had analyzed practically every interesting pool physics problem there is to analyze ... and leather tips had just recently been invented (by Mingaud, another Frenchman, in 1807).

Coriolis was a brilliant mathematician and physicists, and it is amazing how much he was able to do with pool physics, given how busy he was with other things. However, as I will show in some follow-up articles, not all of Coriolis’ conclusions are totally valid because some of his assumptions about how the cue stick, tip, and table cloth respond are not totally accurate. If he had the luxury of a high-speed camera, he would have known about some of these inaccuracies. On the other hand, it is probably good that Coriolis did not have a high-speed camera. If he did, he may not have been as prolific with his work, because he probably would have spent endless hours entertaining himself, colleagues, and students by using the camera for silly things. Believe me ... I know from experience. It is difficult to resist this urge once one sees the creative potential of high-speed videography. On the other hand, if Coriolis had computers in his day (and he would have if he had a high-speed camera), he probably would have gotten a lot more work done. For his pool book, he painstakingly spent days and weeks figuring out conclusions and constructing drawings using (now antiquated) geometric reasoning and analysis. Much of his analysis and illustration work can now be done in a few hours with modern computers and software tools. Anyway, I digress ... now back to his results.

In the remainder of this first article, I will summarize some of the more important and useful conclusions in his book. In future articles, I will summarize some of the interesting things I have learned recently using high-speed videography. I will show how the video results relate to some of Coriolis' conclusions. Then I will look at some of his conclusions in more detail and provide illustrations and advice that might be of interest to people who don't care that much about all of the math and physics.

Here's a brief summary of some of Coriolis' conclusions, which he backed up with theoretical (math and physics) and limited experimental studies:

1. ***The curved path followed by a cue ball after impact with an object ball, due to draw or follow, is always parabolic.*** As shown in **Diagram 1**, the path is parabolic whether draw or follow is used. The shape of the parabola varies with shot speed (see my March '05 article for more information). **NV 4.20** and **4.21** show examples of cue ball paths for typical draw and follow shots. **TP A.4** presents a modern math and physics analysis along with a variety of example paths.

normal video

NV 4.20 – Delay of follow and tangent-line deviation with higher speed
NV 4.21 – Delay of draw and tangent-line deviation with higher speed

technical proof

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

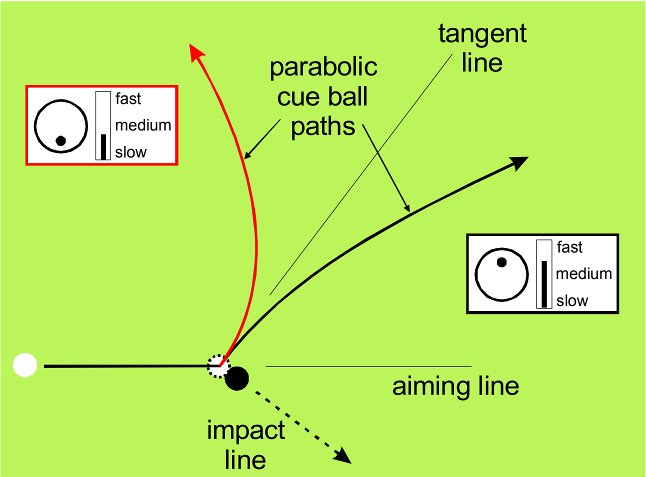

Diagram 1 Parabolic cue ball paths

2. ***To achieve maximum English, the point of contact of the cue tip with the cue ball should be half a ball radius off center.*** See **Diagram 2** for an illustration. For a pool ball (D = 2 1/4 inches, R = 1 1/8 inches), the contact point should be off center by 9/16 of an inch. It just so happens that the radius of the red circle on an Elephant Practice cue ball (this is the cue ball used in all of my NV video demonstrations) happens to be exactly 9/16". The reason for this is that hitting the cue ball with larger offsets can often lead to miscues.

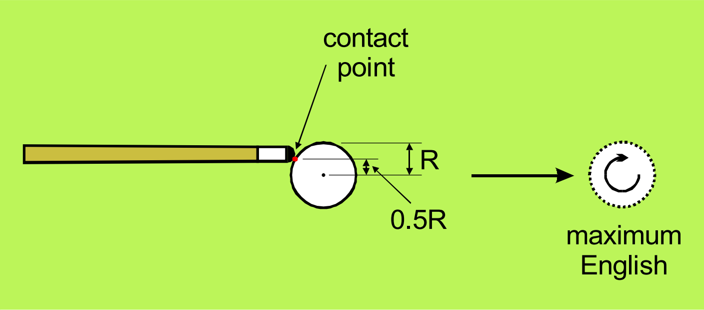

Diagram 2 **Contact point offset for maximum English**

3. ***With a massé shot, the final path of the cue ball will be in a direction parallel to the line drawn between the initial base point of the cue ball and the aiming point on the table.*** This technique is briefly described in Byrne's "Advanced Technique in Pool and Billiards" (on page 49). (In fact, an illustration of the method appears on the cover of that book.) **Diagram 3** illustrates how the method is applied. The final direction of the cue ball path is along line RA, which connects the original cue ball resting point (point R) to the aiming point on the cloth (point A). Using the letters shown in the diagram, with "B" indicating the cue ball contact point, the Coriolis massé aiming system can be referred to as the "BAR" method ("B" for ball, "A" for aim, and "R" for resting point).

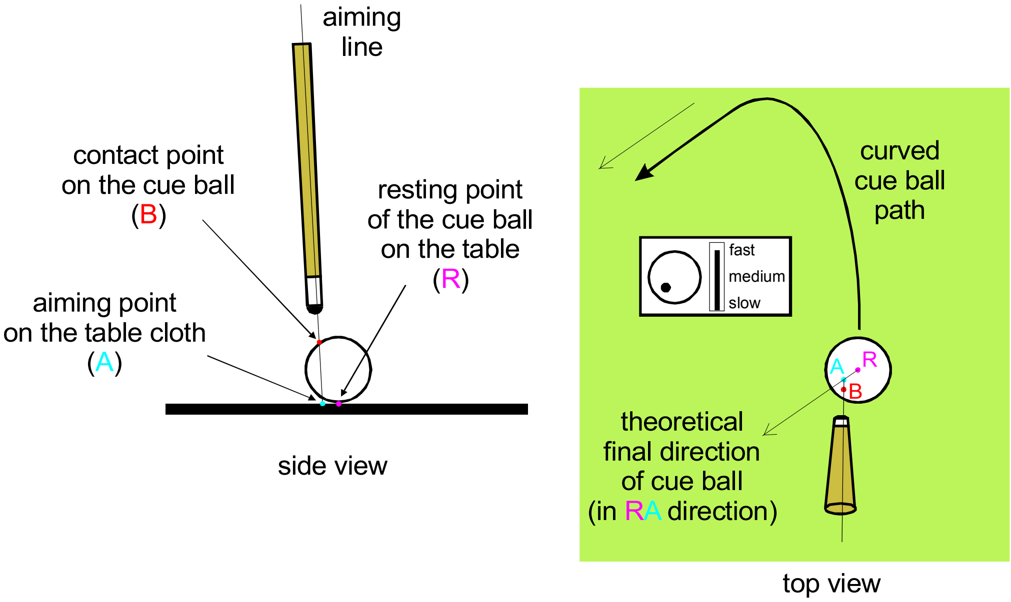

Diagram 3 **Coriolis' ("BAR") massé shot aiming method**

4. ***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°.*** This is very close to a half-ball hit. See my April '04 article for various illustrations relating to a half-ball hit and the 30° rule. For examples of application of the 30° rule and a half-ball hit, see **NV 3.8** through **3.10**. See **TP 3.3** and **TP A.4** for a modern derivation and presentation of the detailed results.

technical proof

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

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

Again, I will look at each of these conclusions in more detail in future articles. I will also discuss when and why these conclusions apply and when they don't. My purpose for this article was just to list the conclusion all in one place for people that haven't had the benefit of seeing Coriois' work. I'll continue the series next month by describing some of the high-speed photography and its place in helping to verify some of Coriolis' conclusions.

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***.
- If you are interested in the physics of pool, you might want to check out the new "Pool/Billiards Physics Resources" section of my website. It lists and provides links to many general interest and technical books and articles that explore the world of pool physics.
- All of my high-speed camera footage to date can be viewed under the "High-speed Video (HSV) Clips" section of my website. I also have a huge collection of non pool (and sometimes silly) clips available for viewing at:

  high_speed_video.colostate.edu

  There, you can find everything from the breaking, smashing, and bouncing of stuff to various stupid human and animal tricks. Enjoy!

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).