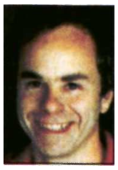
Bob Jewett



Where's The Rub?

More aspects of throw and spin transfer.

About 15 years ago, I had a conversation with Don "The Preacher" Feeney. Don is a student and teacher of the game and plays all three disciplines — pool, snooker and billiards. Don mentioned that he felt that draw and follow changed the cut angle on shots. I remember that he felt that one would increase the angle and the other would decrease it. Since I saw no easy way to test the hypothesis, I put the idea aside for a while.

Since that time, pool researchers have been looking at the problem, and there have been considerable advances in the theory. The important factor is the force that the cue ball generates on the object ball, not by pushing on it (that is what drives the object ball towards the target and away from the contact point), but rather by rubbing on the object ball. Ideally, the object ball leaves the collision with the cue ball along the line joining their centers at the instant of contact. The term "throw" refers to the departure from that line due to friction between the balls.

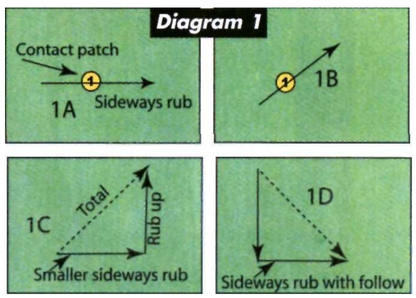
The pushing force is called a "normal force" by physicists because it is perpendicular to the surface of the ball, and "normal" is another word for perpendicular. The force pushes the two balls apart, and in an ideal world, would be the only force players would have to worry about.

The rubbing force is called "tangential," because it acts along the tangent, or kiss line of the two balls. This is caused by the motion of the surface of the cue ball across the surface of the object ball and due to the fact that the balls are not perfectly smooth. To a physicist, this is "sliding friction."

Let's look at a few basic ideas of sliding friction. Imagine you have a cardboard box of stuff on a linoleum floor. You want to slide it across the floor, but it will take a little extra effort to start it sliding because "static friction" is usually stronger than sliding friction. Once moving, the box will require a constant sideways force to keep it moving.

The force required is usually a constant fraction of the weight of stuff in the box. For example, if the contents weighed 100 pounds, it might take 10 pounds of sideways force to keep the box moving. If we doubled the weight to 200 pounds, we would need 20 pounds of pressure to keep the box moving. In this case, we would say that the "coefficient of friction" was 0.1 or 10 percent. So, the harder the two surfaces are pressed together, the more difficult it is to slide them against each other.

There are a couple of wrinkles I've observed in this nice simple theory. If the speed of sliding increases, the friction actually decreases some. The exact result depends on the hidden details of the surfaces. Fortunately, Wayland Marlow in his 1996 book, "The Physics of Pocket Billiards," has already done the measurement for us. He says that friction does decrease significantly



between pool balls as the speed of sliding increases. This is why less throw is observed for faster shots.

A second observation is that the friction seems to decrease with more pressure. Pressure is just force per area, so you would get more pressure if you shot harder. However, we can change the speeds of the surfaces without the cue ball moving any faster. This is done by applying sidespin. The predicted result is that, by using lots of inside English (left English on a cut to the left), there will be less throw than if you play the shot with no English. Looking into the details further, this doesn't apply to nearly full shots, where you have little sideways motion from the cut angle.

During the collision, the balls compress at the contact point. You can observe this by covering the surface of one ball with a thin film of something (such as wax) and then hitting it with another ball. The coating will reveal a round spot. Theory predicts such a spot, and says it depends on the hardness of the balls and the speed of the shot. If you know the time of the contact, you can figure out the size of the contact spot.

Again, Marlow made the necessary measurement, and got a time of about 200-millionths of a second. In a future column we will see why the contact patch is important.

How does this theory apply to the problem at hand of draw and follow increasing or decreasing the cut angle? **Diagram 1A** shows the contact patch on the object ball for a cue ball cutting it without draw or follow. The motion of the cue ball's surface is straight, sideways across the object ball, and the force of friction is also across the ball as shown. The length of the arrow represents the size of the force, and the direction of the force. This force will do two things: First, it will throw the object ball off-line from the ideal cut — it will not go straight away from the contact point, but will be pulled to the side that the rub is acting toward. Secondly, some spin will be transferred to the object ball by this tangential force.

What happens if we add follow or draw to this situation? **Diagram 1B** displays a situation that requires draw on the cue ball. Because of the back spin on the cue ball, the front part of the cue ball, which contacts the object ball, will be moving up. It will also be moving sideways, just from the cut angle. The combination of up and sideways is at an intermediate angle on the surface.

Now, let's go back to our basic theory. The amount of sideways rub is the same, and we have added the upwards rub. This means that the speed of rubbing will be increased over the case where there is no draw. The faster speed of the surface of the cue ball can be expected to reduce the net force (according to Marlow's measurement). This means that the angled arrow will be smaller than the sideways arrow in 1A.

In addition, the angled force needs to be further divided into two parts: One that rubs up only and one that rubs sideways only. From physics, we know that the three corresponding arrows form a right triangle, as shown in **Diagram 1C.** We can see that the sideways force must be less than the angled force, which is the hypotenuse of the right triangle. This is a further reduction of the size of the sideways force, which gives us throw.

Similarly, if we play with follow instead of draw, the cue ball's surface will be moving down as well as across on the surface of the object ball. Again the starting frictional force will be reduced due to the increase in surface speed and further reduced by the hypotenuse to side ratio of the right triangle of component forces, as shown in **Diagram 1D.**

This theory predicts that both draw and follow will have an identical effect, and both will reduce throw during the collision. The theory is nice, but how can we test it?

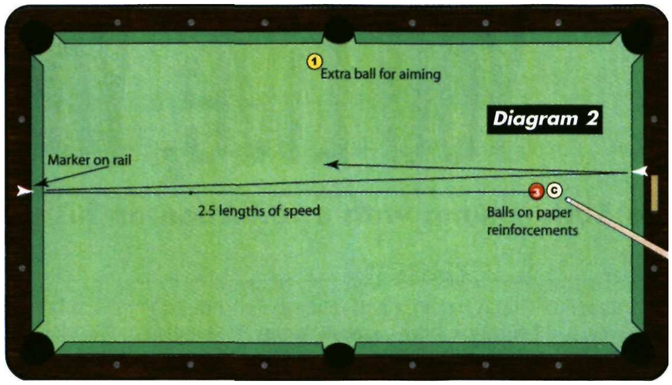


Diagram 2 is a test setup I tried, and I urge you to try it also. The object ball and cue ball are both placed on donut-shaped paper reinforcements to make sure they go back to the same spot each time. They are about 1/4-inch apart. The idea is to play a cut shot with draw, follow and no spin (a stun shot), and see where the object ball goes.

Because the balls are so close to each other, a small change in your cue stick angle will make very little difference in where the object ball goes, but it's still important to repeat the cut angle as precisely as possible. For this purpose, I put an extra ball on the table, and I always shot the cue ball toward it. I chose a speed that would send the object ball up and down and halfway back up the table. I threw out shots that were the wrong speed by more than a diamond or so. I only tried a half-ball cut, which is a 30-degree cut angle, neglecting throw.

I began with the stun shot and placed a coin on the far cushion about where the object ball would land. I repeated the shot a dozen times until I felt that the chosen spot was repeatable for that (lack of) spin on the cue ball. I also noted the landing spot on the cushion I was shooting from, and of course the distance the ball traveled.

Next, I tried draw. The ball — same speed and cut — landed on the far rail, four inches from the spot for the stun shot. I was stunned. While I did expect some reduction in throw from the extra spin on the cue ball, I didn't expect it to be that large. The landing spot on the second cushion was a full 10 inches from the original spot for the stun shot.

Here's a question for you: Is a change in cut of 4 inches in 80 (the length of about six and a half diamonds) big enough to worry about? Remember that a corner pocket, after subtracting the width of the ball, is less than three inches wide, and if you shoot for the center of the pocket, you have to be within an inch and a half of that to pocket the ball.

Question 2: Have you ever consciously corrected the cut angle when using draw on a shot? It was with some trepidation that I approached the obvious next step, shoot the shot with follow. Theory predicted that the ball would follow the same path as with draw, but it just didn't feel right. I should have trusted the theory. The follow shot landed in exactly the same places on the cushions as the draw shot. The theory is correct.

What does this mean for your play? Maybe nothing if you already play stun, stop and follow shots accurately. If you have trouble with cut shots, especially when they are stun shots (without draw or follow, but rather just sliding into the cue ball), then maybe you need some practice with the above ideas in mind.