

Bob Jewett



Charting the Course

Converting spin to speed.

This month we're going to look into details of the physics of straight draw and follow shots. Don't worry about equations and algebra — most of the work is going to be done by a simple graphical tool. Next month the study will be extended to cut shots with draw and follow, and the tool will show us immediately the angle the cue ball will take for any cut angle and any amount of draw or follow.

The basic notion of the tool is that any ball has a speed and a roll, and these can be shown on a diagram with two arrows. A simple rule will tell us how the speed and spin change if they don't "match." Consider a cue ball rolling smoothly on the cloth. From its center, we draw an arrow in the direction of its movement with a length that shows its speed. Physicists call such an arrow a vector, but we'll stick with "arrow."

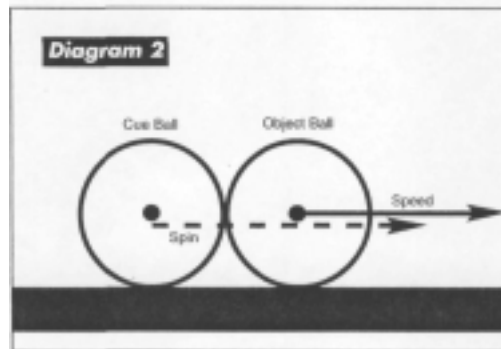
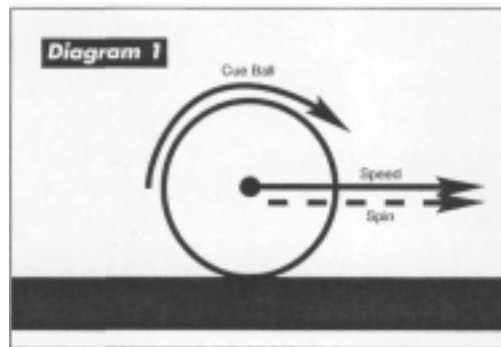
We will also represent the follow or draw on the ball with another arrow. Let's call this the spin arrow, while the first one will be the speed arrow. The speed arrow is shown as a solid arrow, while the spin arrow is shown with a dashed line. Since rolling smoothly on the cloth is the natural state of the cue ball, let's make the two arrows equal in that case.

The arrow diagram for our rolling cue ball is in **Diagram 1**. The two arrows are the same length and in the same direction. How fast is the ball going? That depends on the scale of the arrows. As we'll see below, most of the results give ratios of speeds, so each diagram will apply to all balls in a particular situation without regard to the actual speed or spin. For example, all smoothly rolling balls have an arrow diagram like Diagram 1, regardless of speed.

It's pretty clear that a smoothly rolling cue ball will remain like that until it hits something, so the two arrows will remain matched. Suppose this cue ball hits an object ball full. What is the arrow diagram for each ball right after the collision? In **Diagram 2**, the object ball is shown on the right and the cue ball on the left. At first, the object ball has a speed equal to the original speed of the cue ball and no spin; it's sliding on the cloth. The cue ball is the opposite; it has no speed but retains all of the follow it had just before the collision.

How do these diagrams change the sec-

ond or two afterwards? We all know from experience that the object ball will pick up smooth forward roll, while the stopped cue ball will accelerate forward with its excess top spin until it too is again rolling smoothly on the cloth. The two arrows for each ball will match when each ball reaches that



state, but what happens in the interim?

The amazingly simple rule that describes how spin and speed change to match is this: the tips of the two arrows move towards each other at a constant rate, and the spin arrow moves two and a half times faster than the speed arrow. **Diagram 3** shows how the arrows change with time — perhaps in each tenth of a second. On the top, the object-ball speed decreases while the spin (forward roll) increases. Similarly, the cue-ball spin partly turns into speed. Note that the spin changes more than the speed on each ball, by that factor of two and a half.

The actual rate at which spin and speed balance is determined by the friction between the cloth and the balls. On sticky cloth, the transition period will be shorter; on slippery cloth, or with waxed balls, the equilibrium will take longer to occur. The

first surprising result that we can see from these diagrams is that for our full-follow-shot case, the cue ball and the object ball will reach smooth rolling at the same instant, because the two sets of arrow heads begin with the same separation.

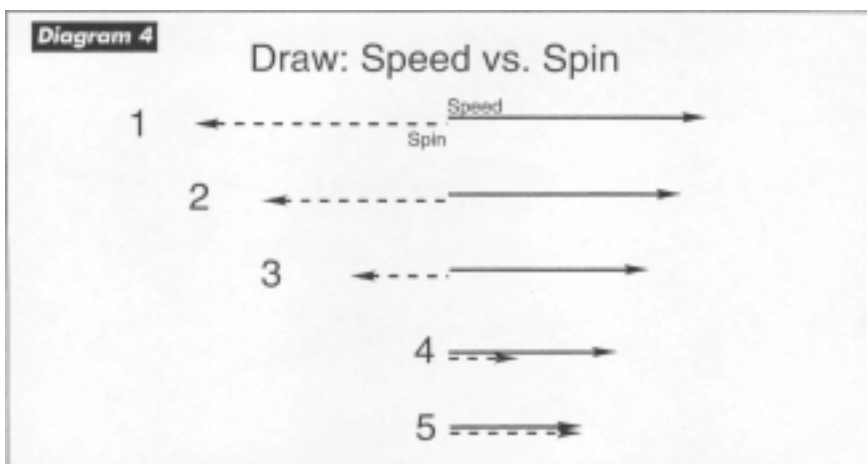
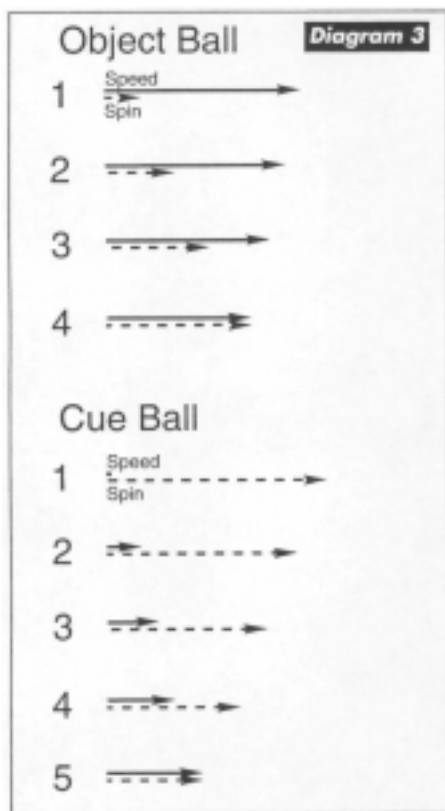
Also note in the diagram that the object ball ends up with more speed than the cue ball. This is because of the 2.5:1 ratio of how quickly the arrow heads change. This ratio is determined by how efficiently a solid sphere (like a pool ball) stores energy in rotation compared to simple forward motion. The ratio of final speeds is also 2.5:1, and if we square this we get the ratio of how far the balls will travel, or 6.25:1. This factor was discussed here in December of last year and is useful to know when playing soft-follow shape; the cue ball will go forward about 1/6 as far as the object ball is driven.

Of course, if the cue ball had no follow or draw when it hit the object ball, it would have neither speed nor spin after the collision, and it would have no reason to move. Suppose the cue ball had "perfect" draw. Then its spin arrow would be back away from the object ball, and would be just as long as its speed arrow at impact. The spin-to-speed transformation would take place just as before, but in the opposite direction. (Remember that "perfect" draw is defined as just as much spin as a rolling ball but back spin rather than follow. It is about the limit of what you put on the cue ball with a level stick.)

What would happen if the cue ball had only partial natural roll when it struck the object ball? If you knew how much follow it had, you could draw the spin/speed arrows for it and find the final result. Try an example with "half-follow" on the cue ball, which you can get by striking the cue ball at about 6 mm above its center. For bonus credit: how far will the cue ball move forward compared to the object ball for this half-follow case?

Where is side spin in all of this? Hiding. Until the cue ball hits a cushion, side spin has almost no effect. The dynamics of draw and follow shots are unchanged by the presence of side spin on the cue ball.

As a last example, consider a cue ball that's struck with perfect draw, but without



an object ball close by. Its arrow diagram is shown in **Diagram 4**, as is the time development of the spin and speed. If you go through the ratios, you'll discover that the cue ball ends up rolling at only 3/7 of its initial speed, and it will go only about 20% as far as a ball that's been struck for "perfect" follow at the same stick speed. This explains the working of the "drag" shot, in which you shoot a long shot harder but with draw so roll-off can't hurt you so badly but you can still land softly on the distant shot.

In next month's column, we'll extend this idea to cover draw and follow with **cut** angles included. This will let you plan any carom with any amount of draw or follow — theoretically, at least. The diagrams will help explain the working reasons for several draw and follows systems that have been covered in previous columns.

Bob Jewett is a partner in the San Francisco Billiard Academy, which offers classes at all levels from beginning players to advanced instructors.