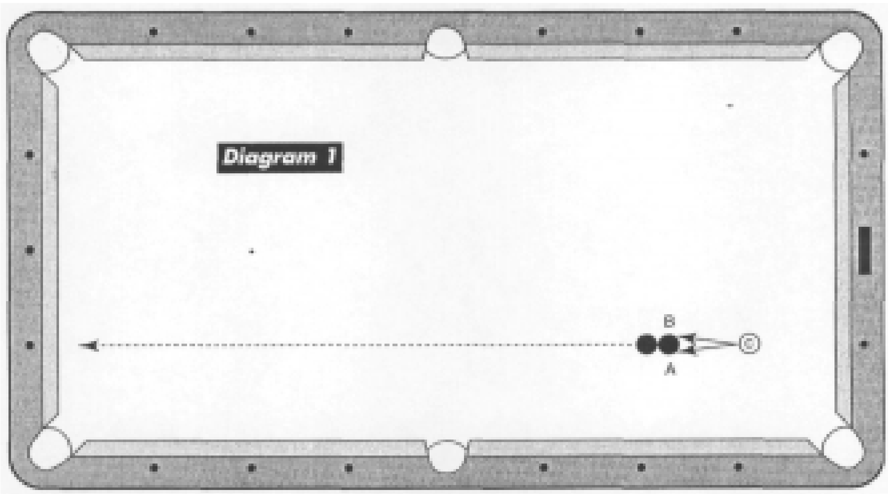
TECHTALK

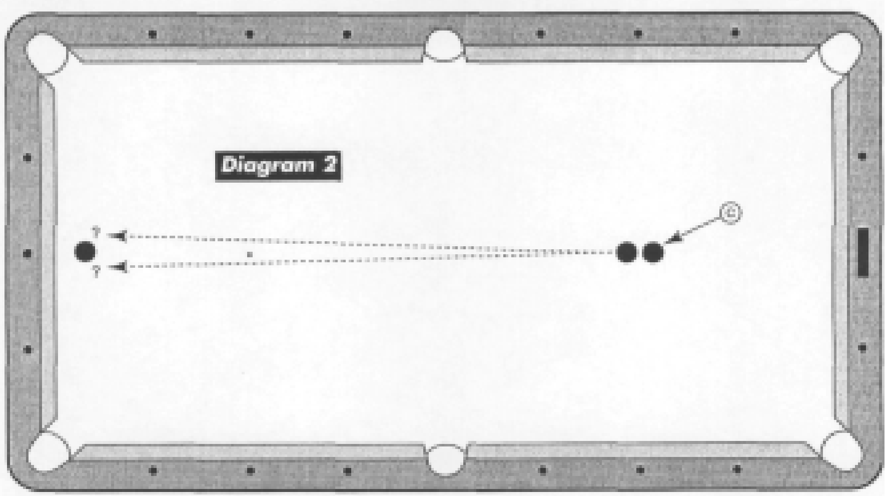
Bob Jewett

Combinations and Throw

Some surprising insights into the world of "throw."

In my column last April, I covered some of the details of throw. Here are two related and surprising experiments for you to try. As a reminder, a ball is said to be "thrown" when its path is not directly away from the spot where another ball contacts it. This deviation can be due to spin on the cue ball, or simply from the motion of the striking ball across the struck ball on a cut shot.





Most beginners will shoot the shot in Diagram 1 wrong. The two object balls are frozen together and pointed about six inches away from the pocket. A novice will attempt to "cut" the second ball by playing to side A of the balls, perhaps expecting the first ball to move to the right before pushing the second ball towards the pocket. Of course, we all know that you have to hit the shot on side B, and let the friction between the balls drag the second ball towards the pocket. But how does the shot change if the balls aren't touching? With some separation, as in Diagram 2, there will be two effects, the throw from the surface friction, and the cut because the first ball does move to the side before it hits the second ball. Which effect will dominate?

If the balls are separated by a hair's breadth, the shot hasn't changed much and you would expect nearly the same result as for frozen balls. With an inch of separation, the cut effect will probably dominate. Our goal in the experiment is to find the separation at which the cut exactly cancels the throw, and the second ball goes straight up the table. In Diagram 2, a ball is placed on the far cushion along the line of the two balls, so we can easily see the amount of cut or throw.

For repeatability of ball placement, get some self-adhesive donut-shaped paper reinforcements. There is a new style available made of thin, tough plastic that can be lifted and moved several times for repositioning. A trick I use for minor tweaks is to place a fingernail as a marker at the edge, and then lift and replace the donut the required distance from the nail.

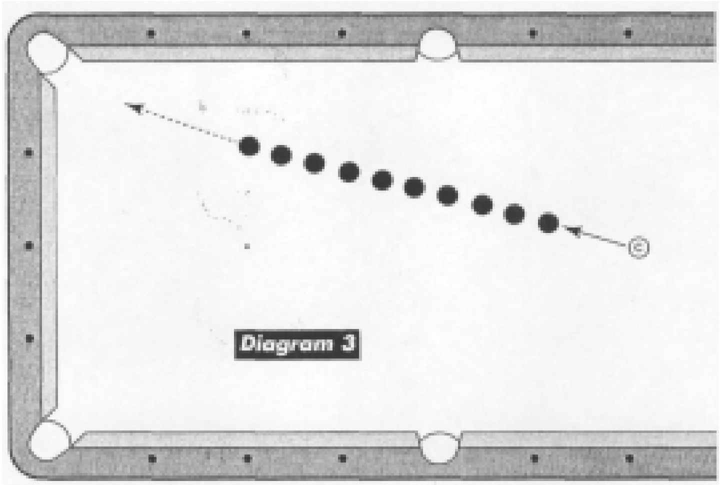
As a first guess, place die two balls one-quarter inch apart. That's probably close to half the diameter of your ferrule, in case you don't carry calipers. Place the rail ball on another donut, and shoot straight along the combination line to be sure that all three balls are in line. Once you have the target in the right place, shoot the shot as an angle combo as shown, with full contact on the first ball, which in turn has a half-ball contact on the ball that's driven up the table.

Is there more throw or cut on the shot? That is, where does the ball land on the far cushion relative to the target ball? Is it the same from the other side? If it's not, something is screwy with your setup or table. Next, try a fuller hit; place the cue ball closer to the line of the shot, so the first ball is driven about 3/4 full into the second ball. What happens for a more extreme angle? Does speed change the shot? If you have the donuts on the table to replace the balls, you can try all of these changes in a few minutes.

Of course, the results will depend on how sticky the balls are. When I tried this shot at a local pool hall, I got cancellation for a half-ball hit when the separation was close to a quarter-inch. This is exactly the rule of thumb that I've used for over 30 years, but I had never measured it before. Common rule of thumb: "If the balls are a quarter-inch apart, there is no throw or cut, no matter how you hit them." Is it a quarter-inch with your equipment?

When I tried a fuller hit, I got a surprise. The throw dominated. With a thinner contact, such as 45 degrees or 1/4-ball full, the cut dominates. The result of this experiment is that the simple rule of thumb isn't accurate, and you need to do some testing under your own conditions. I've seen ball-to-ball friction vary by a factor of two, and this will surely change the "zero-throw" spacing. If you try the experiment, please send me your results in care of *Billiards Digest.*

The second experiment in throw was suggested by Hugh Hilden, who is a professor of mathematics at the University of Hawaii, and who sometimes uses pool problems in his calculus courses. The setup is shown in **Diagram 3,** and is similar to an ancient trick shot. Ten balls are lined up straight to a pocket. The critical factor in the experiment is the separation of the balls. In theory, if the balls are separated by one-ball diameter, any small aiming error you have on the first pair — one degree — will be copied exactly to each subsequent collision.



Suppose you space the balls by two ball diameters instead. Geometry says that any initial error will be doubled in each collision, and with a one-degree error at the start, the sixth ball won't even hit the seventh. There is geometrical growth of the error, and the shot is theoretically nearly impossible.

Where does throw enter? It turns out that throw between successive balls, which is caused by the cut angle of the error, tends to correct the error. This is partly due to the balls being thrown back in line, and partly due to spin that the thrown ball picks up, in the direction which tends to cancel the error.

Professor Hilden reports that when the balls are one ball and a half apart, the shot could be made consistently even when the last ball was two diamonds from the pocket. For this case, the error multiplication factor without correcting throw is about 58, and the permitted error at the end is only five degrees, so the simple theory would require a tenth of a degree accuracy in the aiming. This is a sixth of an inch in the length of the table. With the balls set two balls apart, the percentage was down, but the shot was still possible. With a one-ball separation, the shot becomes unmissable, even with some intentional aiming error. This shot is fun to try, and it sounds like a machine gun when you shoot it. Try it with all fifteen balls.

These experiments will improve your feel for combinations, and the next time you run **into** either multi-ball or not-quite-frozen combos, you'll be ready. And if you're a junior player deciding about college, consider math at the University of Hawaii. You may have already done the homework.

Bob Jewett is an Advanced-level BCA Certified Instructor.

TECHTALK

Bob Jewett

Newton on the Ball

The flaws of the 90-degree rule.

Guest columnist (and fellow billiard-physics fanatic) Dr. George McBane is a professor of chemistry at Ohio State University, where he and his graduate students study collisions between molecules. Tools used there can be applied to billiard balls, as you will see.

Anyone who has played pool for more than ten minutes has figured out that the thinner the cut, the slower the object ball goes, and the faster the cue ball goes after they collide. And the first thing most players are told when they start to learn position play is "After the collision, the cue ball leaves at right angles to the object ball's path." The first of those statements is true, the second is only sometimes true.

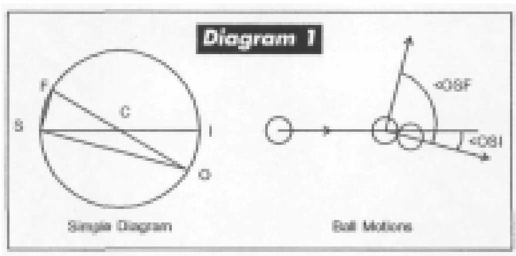
People who study collisions—of planets, of subatomic particles, of balls—use a simple diagram, called a Newton diagram (after Sir Isaac) or velocity vector diagram, to help figure out what laws of conservation of energy and momentum require of a collision.

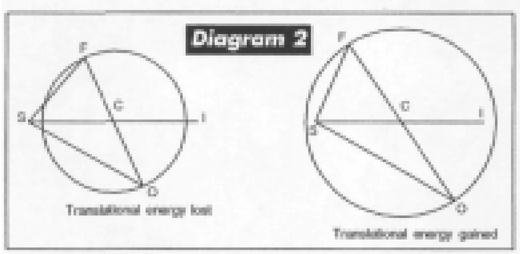
The diagram is easy to draw. Cueists can use it to show how fast the cue and object balls will go in a cut shot, what the angle will be between the cue and object balls' paths after a collision and how the behavior of the balls will change if the cue ball is lighter or heavier than the object ball. It can also occasionally disprove plausible-but-incorrect statements about how balls behave, including the "right-angle rule."

The simplest version is shown in Diagram 1, along with the shot it corresponds to on the table. To draw it, start with a line along the direction you will shoot the cue ball. The line's length represents the cue ball's speed just before the collision.

Mark the beginning of the line with S (for "stationary"), and the end with I ("initial"). At the midpoint of that line, put a dot (C). Draw a circle with its center at C that passes through S. Now, starting at S, draw another line, parallel to the path the object ball must take to the pocket; extend it until it touches the circle. Mark the point of its intersection with the circle O ("object"). Draw a line from O through C to the circle on the other side; mark that intersection F ("final"), and finally draw a line from S to F.

The line from S to O gives the direction and speed of the object ball after the collision. The line from S to F gives the direction and speed of the cue ball. It's easy to see that as the cut angle (the angle from I to S to O) gets bigger, the object ball speed will get smaller and the cue ball speed will get bigger, until finally for a perfect 90-degree cut the object ball will not move at all and the cue ball will go straight forward without slowing down. If you remember your geometry, you might also be able to show that, with this diagram, the angle between the final cue and object ball directions is exactly 90 degrees, no matter what the cut angle is; the "right-angle rule" is correct in this case.





In carom games, one-pocket and safeties at pool, it is often important to control the speeds of both object ball and cue ball, and this diagram can show you how those speeds vary with the cut angle (The diagrams tell you only about the collision between the balls, so they apply directly to stun shots. Follow or draw will affect the speed and direction of the cue ball; those effects must be "added on" to these).

What assumptions lie behind this picture? First, these diagrams assume that all the action takes place in a single plane. If the cue ball is airborne, or is different in size from the object ball, the slate enters the picture in an intimate way and the diagrams are not as useful. Diagram 1 also assumes that the cue and object balls have the same mass, and that the total translational energy (energy of motion along the table) is the same before and after the collision. These latter assumptions are often violated, and slightly different diagrams must be used.

It's rare for there to be no change in the translational energy. Usually there is some change in the spins of the two balls during their collision, so that translational energy is converted to rotational energy or vice versa; to prevent that, you have to either hit a straight — in stop shot, or you have to hit a stun shot with just enough outside english that the surfaces of the two balls do not rub together when they collide. When the balls do rub together, some energy changes from moving the balls along the cloth to making them spin, or vice versa. Some also goes to producing the sound of the hit, and some warms up the balls; both of those amounts are usually too small to worry about.

In the Newton diagram, changes in translational energy change the size of the circle. In the majority of shots, translational energy is lost, and the circle gets smaller. This is true for shots where the throw tends to decrease the cut angle: inside English, center ball, or little/enough outside English that the cue ball still "slips forward" on the object ball as it hits. If you use enough outside english that the cut angle is increased (which is easiest for nearly straight-on hits), then some of the initial spin of the cue ball ends up as translational energy, and the circle can get bigger.

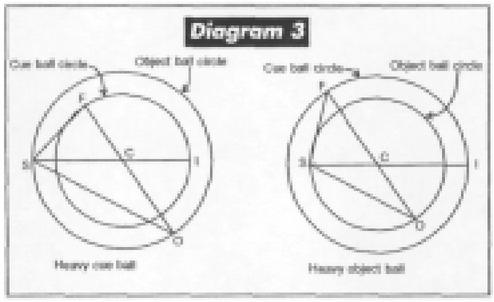
Diagram 2 shows how this works. The two diagrams drawn there are both for 30-degree cut shots to the right. On the left, the shot was hit with center-ball. At the moment of contact, the balls rubbed together, and the friction from that rubbing threw the object ball to the left and imparted some clockwise spin to each ball (See *Tech Talk,* April 2000). The throw has no effect on the diagram, since the line from S to O was drawn in the direction the object ball actually traveled. It takes energy to makes the ball spin, though, and that energy comes from the initial translational motion of the cue ball; that makes the circle smaller, so that the line from O to F is shorter than the line from S to I. Now the angle from O to S to F is less than 90 degrees.

On the right, the same shot was hit with heavy outside (left) English (The player aimed differently than on the left, so that the object ball would still leave in the same direction—toward the pocket). In this shot, when the two balls came together, the rubbing between them was in the other direction; the object ball was thrown to the right and picked up a little counter-clockwise spin, and the cue ball lost spin. The **translations!** energy increased overall, so the line from O to F is longer than that from S to I. Now, the angle from O to S to F is larger than 90 degrees; the separation angle widens in this case.

How big are these changes in separation angle? It's reasonable to think of them this way: the cue ball always leaves at right angles to the line between the two ball centers at contact, while the object ball will be thrown to the right or left of the line between centers. So, the changes in separation angle are the same size as the throw angles, and with clean balls those are rarely bigger than five degrees. That argument is not exactly right; some energy is lost to heat and sound, and the balls do move slightly during the time they are in contact so the "line between centers" is not precisely defined, but it gives a good estimate of the maximum change from right angles.

You can occasionally use these changes in separation angle to maneuver around an obstructing ball in your path to the next shot, or even to take a free carom shot at the nine ball while still pocketing your main object ball. The diagrams also show that it is not possible to make a cut shot without having the cue ball move in the direction opposite the cut, as is sometimes claimed.

If the cue ball and object balls do not weigh the same, there is a dramatic effect on the cue-ball path. This situation is most common on coin-operated tables, but can also appear on other tables if the cue ball is mismatched or worn. To draw this diagram, instead of placing point C at the midpoint of the first line, you put it at the "balance point": the point where a light, stiff rod with its ends at S and I would balance if the cue ball was put at I and the object ball at S. In other words, the distance CI times the cue ball mass must equal the distance CS times the object-ball mass. Then, draw two circles. One should have its center at C and pass through I; that is the "cue-ball circle." The other, the "object-ball circle," has its center at C as well, but passes through S. Then draw the line from S in the object ball travel direction as before, and label its intersection with the object ball circle O. Draw a line from O through C and on to the cue ball circle; its intersection with the cue ball circle is F. Finally, draw the line from S to F that shows the final direction and speed of the cue ball. **Diagram** 3 shows a heavy cue ball (left) and a light cue ball (right). (Translational energy changes would make both circles smaller or bigger; Diagram 3 shows the case where there is no change.)



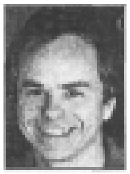
If the cue ball is heavier, the separation angle varies smoothly from zero for a straight — in hit to 90 degrees for a very thin cut. A heavy cue ball produces "instant follow"; the cue ball will start out moving forward of the right-angle line, even if it arrives with back spin, and before friction with the cloth has had any effect.

If the cue ball is lighter than the object ball, then you get "instant draw." For a straight — in shot, the cue ball will back up after contact even if it did not have any spin (Think of throwing a soccer ball at a bowling ball). As the cut gets thinner, the separation angle will decrease from 180 degrees, and finally for very thin cuts it will approach 90 degrees.

For both heavy and light cue balls, the most dramatic effects appear for shots near straight in. Because the separation angle changes dramatically with the cut angle, carom shots are much more difficult with mismatched balls.

—George C. McBane

Bob Jewett



Weird Techniques

Get a better grip on hard-to-reach shots.

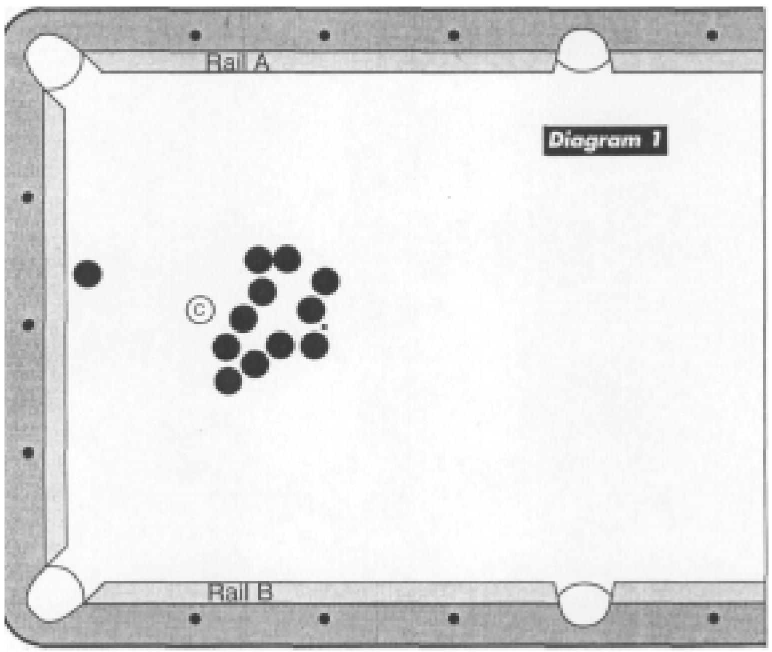
With perfect play, every shot is going to look the same: comfortable stance without stretching; smooth, straight stroke; easy position on the next ball using little or no spin; repeat. This can be dull. When players get into trouble, you get to see some interesting techniques. You should learn some of these — at least the legal ones — so you'll be ready on those rare occasions when you get out of line.

One common question is what to do when you can't reach a shot normally. The standard techniques are to use a mechanical bridge or shoot opposite handed, and both of these should be part of your practice. Suppose, though, that you're faced with the shot in Diagram 1, and your name isn't Shaquille. You need to hit the ball on the cushion, and most of the rack is in the way.

The standard method for this situation is to place one mechanical bridge on top of another to get added height — the top bridge's shaft goes in the slot where you would normally put your cue stick. It can also help to turn one or both bridges on their sides to get more height. If lots of balls are between you and the cue ball, the top bridge can be pushed forward to cantilever out over the obstructions. Be sure to grip both bridge handles firmly together for stability. As with most bridge shots, don't be ambitious about what you are going to do with the cue ball; easy does it. If you haven't practiced this one before you need it, good luck. It is illegal to stack more than two bridges. It's also illegal to rest your hand on top of the rack, even when playing by "cue-ball fouls only."

There are several bridges on the market that help with this kind of shot. At snooker, a bridge (snooker players call it a "rest") with a long "swan's neck" that arches out over obstructions is available. Another snooker bridge called the "spider" has feet wide enough and long enough to straddle a single ball — think bow-legged. On this side of the pond, bridges are available that lock together for additional stability.

A more creative use of the bridge on this shot is to place the head on rail A and the butt at rail B. The bridge handle will be high enough to clear the obstructing balls. Now place your hand on the bridge handle and form a more or less normal bridge for the shot. This technique seems to be legal.



Another technique is useful when you need to hit the ball pretty hard, and you don't trust the mechanical bridge for that much power. An example would be at billiards where you have to take the cue ball off the left side of the object ball in Diagram 1 and go six cushions for the score. The shot can be reached from the side of the table, but you can't get your head over the cue stick to sight. Raymond Ceulemans has been known to place the cue stick on the correct line while standing at the other end of the table, walk around to the side, carefully pick the stick up without moving it off line, and then stroke "blindly." Under Billiard Congress of America rules, this is legal provided that you maintain contact with the cue stick.

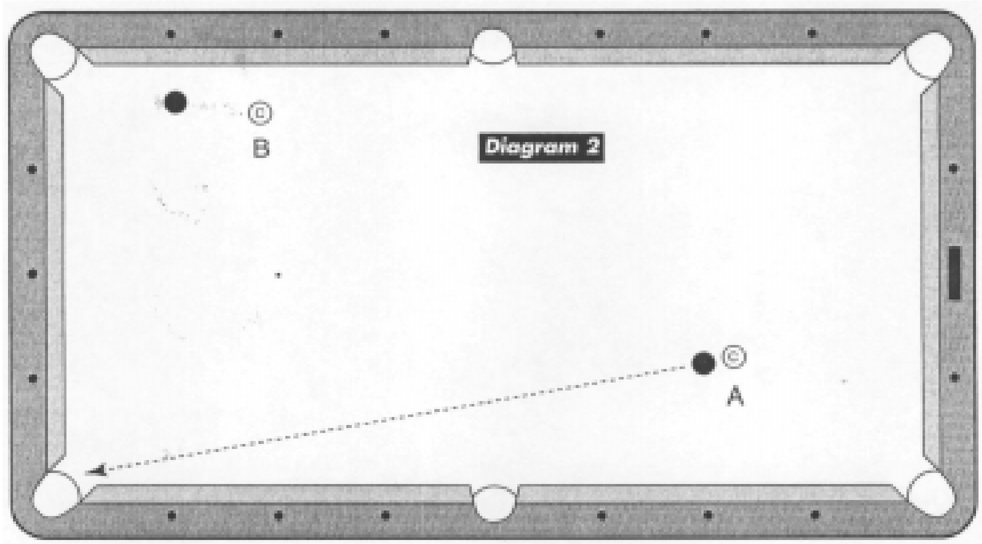
Jump shots are so common now that they hardly deserve mention, except for the wrong ways to do them. It is not legal to make the cue ball clear an obstructing ball by miscuing (scooping the ball). It is not legal to shoot jump shots with just your shaft. Shaft jumping is effective because the resulting very light stick stops on contact with the cue ball and lets it rebound freely from the table. It is not legal to use a very hard material such as phenolic for a tip. Such "tips" seem to help the cue stick stop faster, but can be hard on the equipment.

Speaking of miscues, Shot A in Diagram 2 shows where some players are tempted to use an intentional miscue. The cue ball and object ball are pointed straight at a pocket, but are only a quarter of an inch apart. The problem is to avoid hitting the cue ball a second time as the cue stick follows through. If you aim to hit the cloth and the ball at the same time, a miscue will result, and the cue ball will hit the object ball and jump straight up in the air. Players who try this in tournaments protest the resulting foul call because they say they were not playing a jump shot, but the shot is ruled a foul nonetheless.

A legal technique for 2A is to move your grip hand forward so that it will be at the rail just before the tip hits the ball. If you stroke with the stick rubbing the rail, your hand will smash into the rail and stop the stick before it hits the cue ball a second time — correct placement of the grip hand is critical to getting power without a foul. This technique was said to be a favorite proposition of Luther Lassiter. With practice, it doesn't hurt much.

Diagram 2B shows a straight — in shot that requires draw. Being right-handed, you can't reach it, and the mechanical bridge is missing in action. Jerry Briesath has the cute solution: lay your stick flat on the table with the tip nearly at the cue ball. With your left hand, pinch under the stick just a little at the joint so the tip is the right height on the cue ball. Now jam the heel of your right hand into the rubber bumper on your stick. Jerry can draw the cue ball the length of the table. Can you? I suppose a pencil under the stick would also work to raise the tip to the right height, but that would be Illegal Use of a Device.

One technique for getting a lot of side spin is to aim as if for no English and then swerve to the side on the final stroke. Some players claim this works but I doubt that it gets more spin that coming straight through, and I can't think of a better way to destroy consistency. Semih Sayginer and Mike Massey seem to get enough spin without this technique. The only benefit of this method is that it can compensate for squirt under some conditions.

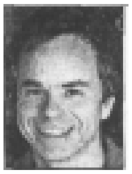


A related technique some professional players use is to always set up at the bottom of the cue ball and then hit high, low, left, right, center or anywhere. The rumor is that old-time players used this to baffle their opponents. There is one thing it will help with: If you have a problem seeing where the center of the cue ball is, starting at the bottom is the best place to see if you are centered.

Masse shots give plenty of room for "interesting" techniques. Grips include the regular, the "dart" grip, and "The Claw." For this last grip, get into full masse position, and make a "V for victory" sign with your grip hand, palm down. Put the stick into the V and then curl your two fingers to grab the stick between them. You can get surprising power with this grip. If the owner of the table asks, you don't know me.

Have you seen something really strange on the pool table? A technique, that is. If so, let me know about it, in care of this magazine, and I'll describe it in a future article. In the meantime, perfect the above tricks. You won't need them often, but they're interesting to try, and it's good to be prepared.

Bob Jewett



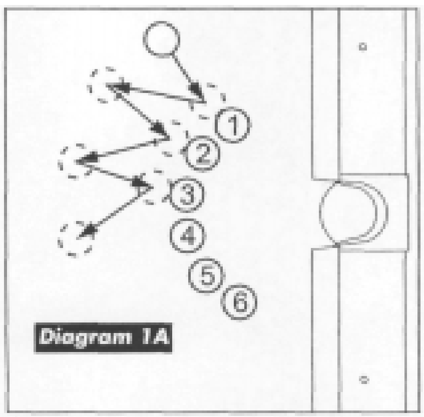
TECHTALK

Three Draw Drills

Something old and something new.

How's your draw? I recently was working on mine to improve my finesse position for one-pocket and 14.1. The following drills have something new and challenging even for the old hands.

I saw the first drill nearly 40 years ago in Willie Mosconi's *Winning Pocket Billiards.* Place a number of balls in a semi-circle around the side pocket and shoot them in order. Where the balls start is up to you; I find it's best to put the balls as close to the pocket as possible without blocking a shot. You are not allowed to touch any cushion with the cue ball or to bank an object ball. Reset all the balls as soon as you have missed a shot.



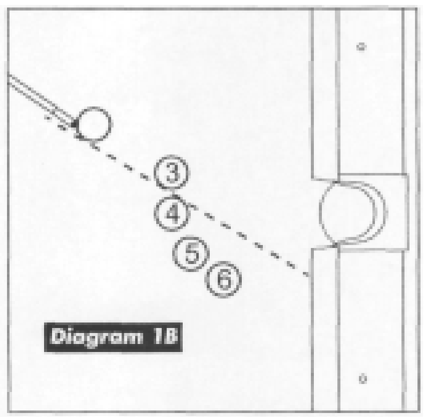
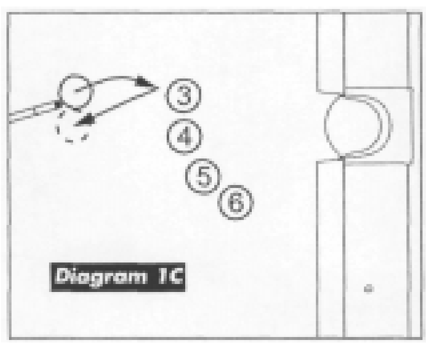


Diagram 1A shows how the start of a perfect run looks. The cue ball follows a zig-zag path; after each shot it comes to rest about eight inches from the next ball, and lined up so that a shot to the center of the pocket gives just enough angle to get to the next ball. You will quickly learn what that angle is, but a good rule-of-thumb is to leave the cue ball so that shooting full at the object ball will barely put the ball in on the right side of the pocket.

Now for a new wrinkle on this old drill: if you make all the balls without a miss, add one ball to the semi-circle for the next run, but if you fail, subtract one ball from the next set. This is now a form of "progressive practice" and you can keep track of how you are doing by simply noting how many balls are in the present semi-circle. If you need a grade for motivation, three is a C, six is a B, and nine is an A.

Diagram IB shows a problem you will likely encounter. The cue ball stopped too soon for a good shot on the 3 ball as shown by the dashed line, which points down the rail several inches past the pocket. If you have perfect soft draw and cheat the pocket to the verge of missing, you may be able to keep the cue ball from going past position for the 4 ball. In this situation, try using as level a cue as possible and right English with the draw. The idea is that the side spin will throw the object ball into the pocket so that not as much cut angle is needed. It will take you a while to get the feel for this. Accurate aim is mandatory, since you will still have to cheat the pocket.

Diagram 1C shows the opposite problem; the cue ball has wandered too far and is on the wrong side of the 3 ball. You need to hit the object ball on the left side and get the cue ball to come to the right. Amazingly, the answer is once again right side-spin. The trick is to elevate to about 45 degrees and play a half — masse shot. The cue ball will curve before and/or after hitting the 3 ball, and with the right touch will get back in line for the 4 ball. This shot calls for a solid raised V — bridge and finesse. Don't shoot it like you're killing snakes; instead, it should be more like kissing your Grandma.

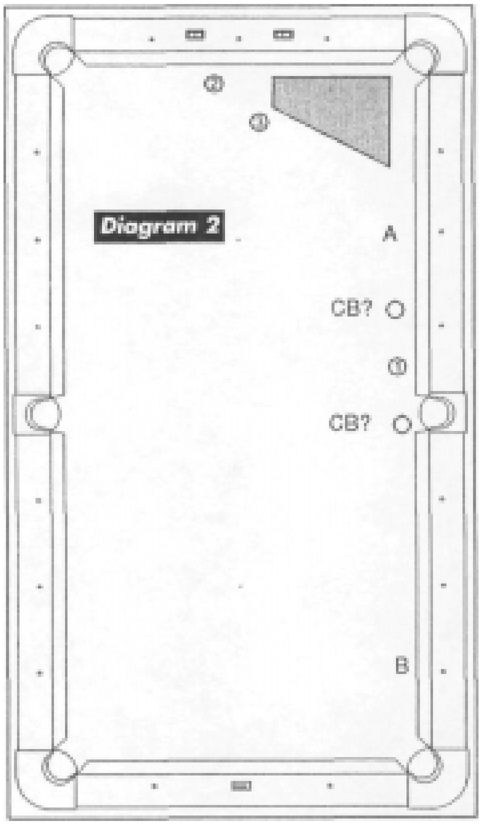


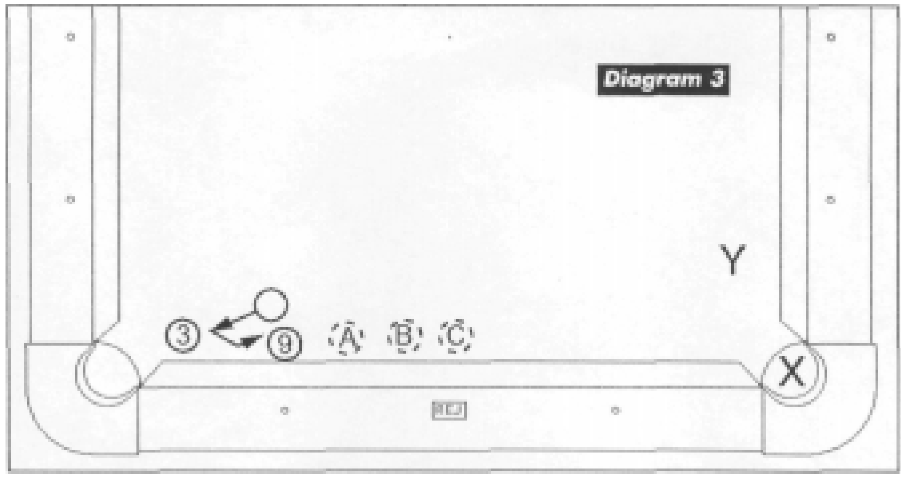
In Diagram 2 is a chance for you to test the idea that follow is better than draw for position. You have ball in hand on the 1 ball at a game of 9-ball, and need to get to the shaded area for a shot on the 2 ball. Should you place the cue ball on the A side for draw or the B side for follow? Try each way 10 times to see which works best for you. If you have trouble with the fallow shot, the most likely problem is failure to hit high enough on the cue ball; the higher you hit, the less speed is needed for the position. Next try placing the 1 ball at A. Is draw better than follow now? Finally, place the one ball at B. There is a rule-of-thumb that says with ball in hand, you should never place the cue ball for a draw shot. Is any of these shots an exception for you?

Finally, Diagram 3 is an interesting draw drill that can be used as a challenge. The goal is to pocket the 9 ball in Pocket X with a draw-carom after pocketing the 3 ball. You don't have to get the 9 all the way there in one shot, though; leave it where it rolls to and try again. The 3 ball comes back up to the same position, and the cue ball is in hand for each try. The positions A, B and C show possible successive positions of the 9 if you shoot softly. And it is good to land softly on the 9, since this will teach you precise finesse position. Softer shots also tend to keep the 9 near the cushion where it is easy to get to. If you fail to touch the 9, start the drill over.

While you work on this drill, try to get a feel for the angle the cue ball draws to for a particular cut angle on the 3 ball. With a little practice, you'll be able to pull the cue ball right along the end rail even with a starting angle over 30 degrees. For this drill, you will probably want the tip as low as possible on all shots to minimize the cue-ball speed. In the first drill in Diagram 1, it is often useful to take a little draw off the ball to keep from pulling back to far.

One variation is to go for as many contacts as possible. For this, soft shots are mandatory, and hitting the cushion with left side spin seems to keep better control of the cue ball. My record is about 18 shots before pocketing the stripe. Another variation is to go for the fewest shots, but you'll see that much better accuracy is required.





One last word on this drill. If you over-do it and run the 9 ball to Y, not all is lost. Very carefully line the cue ball up between the 3 and the upper edge of the 9, and then do your best to draw the cue ball perfectly straight back to hit the 9 on the upper edge. This shot is worth a couple of tries even if you miss the first time, just to get a feel for this very precise skill.

For all of these drills, remember to change sides. The shot may look a lot different to you when it's reversed. Of course, the shots in Diagram 2 may need a bridge on one side for players who don't switch hands. Draw is always a good skill to have ready for position play. Finesse-draw is even better.

Bob Jewett is an Advanced-level Billiard Congress of America-certified instructor and partner in the San Francisco Billiard Academy, which is BCA-certified for instructor training.

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.

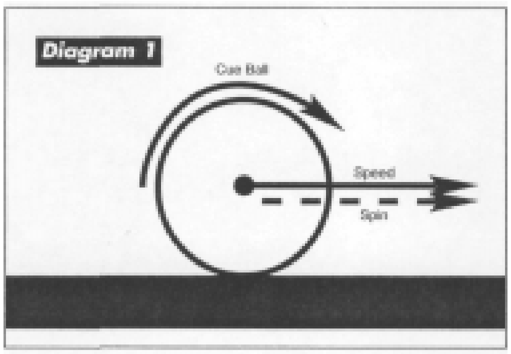
The basic notion of the tool is that any ball has a speed and a roll, and these can be shown on a diagram with two arrows. A simple rule will tell us how the speed and spin change if they don't "match." Consider a cue ball rolling smoothly on the cloth. From its center, we draw an arrow in the direction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

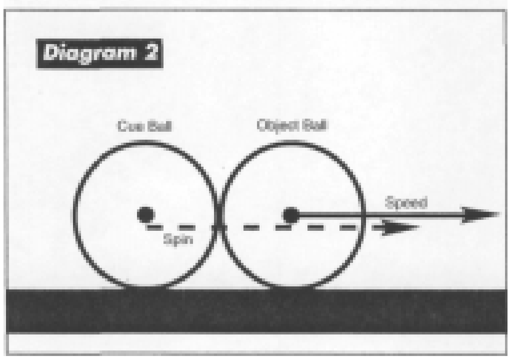
We will also represent the follow or draw on the ball with another arrow. Let's call this the spin arrow, while the first one will be the speed arrow. The speed arrow is shown as a solid arrow, while the spin arrow is shown with a dashed line. Since rolling smoothly on the cloth is the natural state 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 second 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.

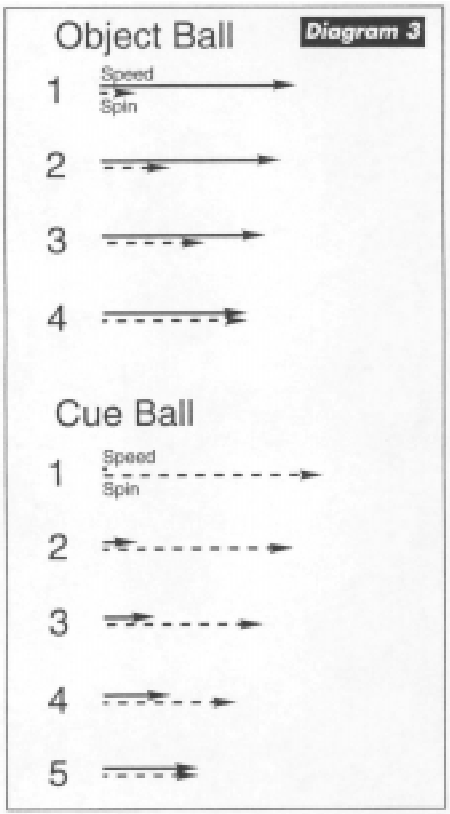
Also note in the diagram that the object ball ends up with more speed than the cue ball. This is because of the 2.5:1 ratio of how quickly the arrow heads change. This ratio is determined by how efficiently a solid sphere (like a pool ball) stores energy in rotation compared to simple forward motion. The ration 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.

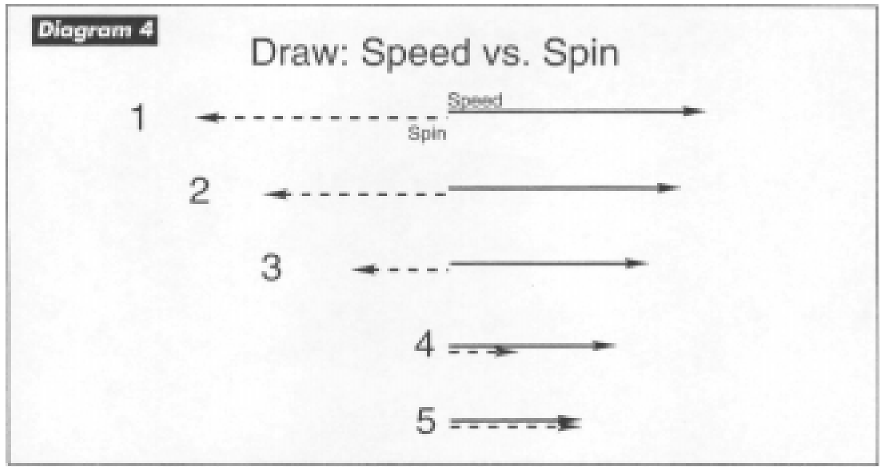
Of course, if the cue ball had no follow or draw when it hit the object ball, it would have neither speed nor spin after the collision, and it would have no reason to move. Suppose the cue ball had "perfect" draw. Then its spin arrow would be back away from the object ball, and would be just as long 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



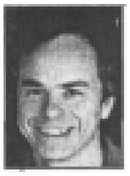


an object ball close by. Its arrow diagram is shown in **Diagram 4,** as is the time development of the spin and speed. If you go through the ratios, you'll discover that the cue ball ends up rolling at only 3/7 of its initial speed, and it will go only about 20% as far as a ball that's been struck for "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.

Bob Jewett

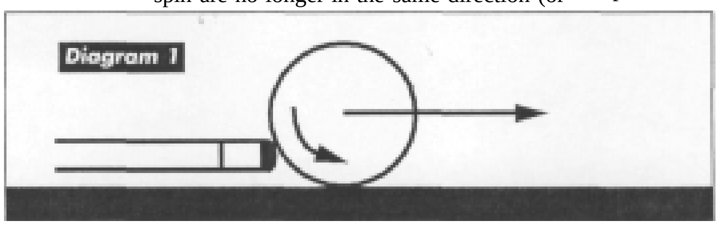


TECHTALK

Drawing Draw

Part 2 of charting the cue ball's path.

Last month I described a graphic technique for understanding how draw and follow interact with the forward speeds of the cue ball and object balls, and how speed is converted to spin and vice versa. The basic idea is shown in **Diagram 1,** where the cue ball is struck with draw. If there is no object ball in the cue ball's path, the speed and spin arrows evolve as shown, with the spin (draw) arrow, getting shorter and finally turning into follow as the speed arrow decreases from the initial value due to the drag from the draw. An important point is that the spin arrow changes five units for each two units that the speed changes. Another is that the two arrows move at a constant rate towards each other. That constant rate is determined by how slippery the cloth is.



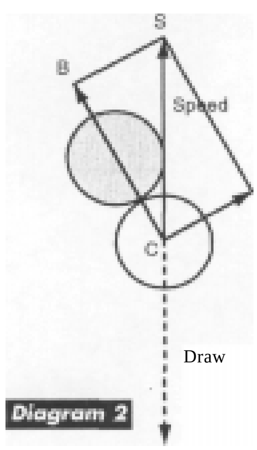
Spin (draw) Speed

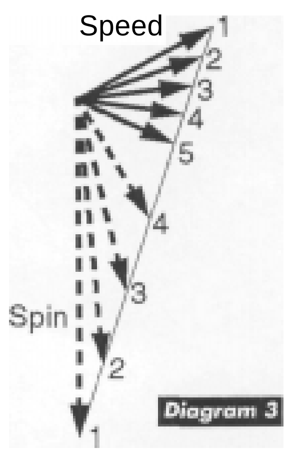
1

2

Spin (follow)

While this analysis is both interesting and useful, the real action starts when the cue ball hits an object ball at an angle. At that instant, the speed of the cue ball, which was in line with the draw or follow arrow, is knocked by the collision to a different line with a different speed. In **Diagram** 2 the cue ball that we loaded up with draw is seen from above as it hits an object ball for a half-ball hit. The initial speed and spin are equal, and in opposite directions. Remember that we called this amount of draw "perfect," as there was just as much draw as a smoothly rolling ball would have follow.





What does the speed of the cue ball become? To find it, draw a rectangle as shown in the diagram. One corner is at the center of the cue ball, and one side is along the line joining the centers of the cue ball and object ball. The final detail that completely sets the rectangle is that the speed arrow of the cue ball is a diagonal of the rectangle. Believe it or not, there is only one rectangle that satisfies these three requirements.

The new speed arrow of the cue ball is exactly the side CA, and the speed arrow of the object ball is side CB. This is a strange situation for the cue ball. The speed and the spin are no longer in the same direction (or along the same line) — what happens to each, and where does the cue ball go?

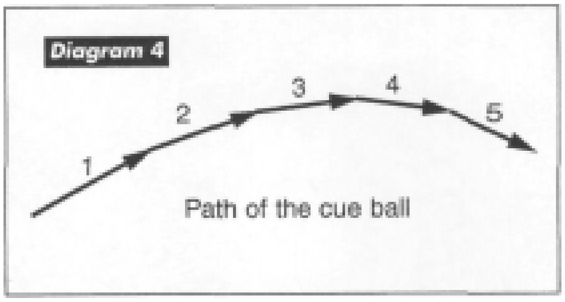
The two arrows still move according to the rule given earlier. They move towards each other (along a straight line) with the spin arrow changing 2 1/2 times as fast as the speed arrow. This is shown in **Diagram 3,** where the successive arrows are shown for five different times in sequence. At 5th-time sequence, the arrows are the same length and in the same direction, so the change stops at that point.

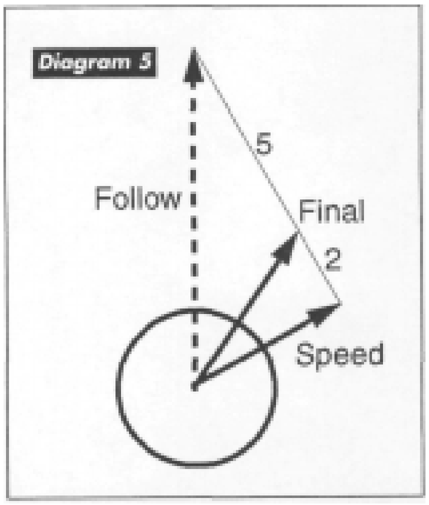
What sort of path does the cue ball follow during this time? It is easy to get a close approximation of the path by joining the speed arrows head-to-tail in order. **Diagram 4** shows what this looks like; the path shown is roughly a curve. If we used twice as many times, with the times more closely spaced, the ten arrows would form an even smoother curve. Technically, the ideal curve is a parabola, which is also the path a ball follows when thrown. At the end of the curving part of the path, the cue ball will continue to roll along the direction of Arrow 5, since by then the speed and spin have reached their happy common equilibrium.

This draw shot repays time spent in practice. Notice that the final path of the cue ball is a little past the perpendicular to the initial path. (The calculated angle is about five degrees.) Previous columns, including Dr. George Onoda's column in May 1989, suggest that it is hard to pull the cue ball back behind the perpendicular. How does the shot work for you? (It's no fair if you cheat by hitting more than half the object ball.) If the perpendicular is your limit, what are some reasons you might not be getting the angle predicted for "perfect" draw?

Usually the final direction of the cue ball is far more important than the exact curve it takes before it settles into that path. A simple case is shown in **Diagram 5.** This is the same shot as in Diagram 2, but with follow rather than draw. The speed is the same, but the spin is in the opposite direction. The final direction can be found by joining the speed and follow arrows, and then finding the point along that line that divides it in the ratio of 2:5.

The angle between the initial and final paths in this case is a very important one to know; it is the natural angle for a half-ball





hit. Position play that involves anything close to half-ball (a 30-degree cut) and a rolling cue ball will produce a deflection angle very close to this (about 34 degrees).

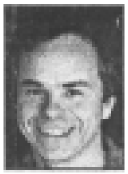
The geometry of the rectangle and the arrows can be used to develop various systems for cue-ball control. For example, you can show that if you play a follow shot with a small cut angle to the left, the cue ball will be deflected to the right by 2 1/2 times the angle. In a previous column, I suggested 3 as the ratio. See what happens for you with real balls on real cloth.

Where does this factor of 2:5 come from? Roughly stated, it says how much more effective the simple movement of the mass of the ball is than the movement you get from the spin rubbing on the cloth. Physicists call this the "moment of inertia." The usual assumption is that the ball is uniform, but this is not always the case. Some cue balls have heavier centers, and the effectiveness of spin on such balls is smaller; they would be more lively if they were hollow with a heavy shell. Think about it this way: if you had a bicycle tire made out of lead, it would be hard to stop its spin by grabbing the rim, but if all the lead were in the hub, the spin would be much easier to stop with that long lever arm from the spokes. How large is the effect for cue balls? It seems to be no larger than the effect of the cue ball's being small and light from wear.

In theory, this graphic system for figuring out where the cue ball will go can give you precise results. Since it depends on knowing how much spin the cue ball has, the easiest case is when the cue ball is rolling smoothly on the cloth. Fortunately, playing with a smoothly rolling cue ball is the easiest way to play position, next object ball willing. This system may also be useful for letting you know which shape shots are impossible — the speed arrowhead can be pulled over only so much by the spin arrow. This system can even be applied to masse shots, and for a given stick elevation and offset, you can draw out the curved part of the path as in Diagram 4. That extension will have to wait for a future column.

Bob Jewett is an advanced-level Billiard Congress of America Certified Instructor and a partner in the San Francisco Billiard Academy, which offers classes at all levels from beginning players to advanced instructors.

Bob Jewett



TECHTALK

The Rack

It's more than a torture device.

One way or another, a major change is coming to pool. The advent of the Sardo Tight Rack is forcing players and officials to re-examine what a rack should be and how to deal with a nearly perfect framing of the balls. At least one rule has already changed, although you might not have noticed.

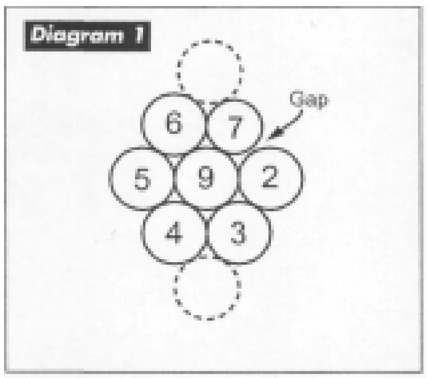
Let's begin by asking a question: Should the rack be tight? The norm for many lazy and/or cheating rackers is to leave a sloppy, loose grouping of balls on the table, resulting in a break that is unpredictable and often ineffective. The rules require — and I think it's only fair — that the balls be racked as tightly as possible, but how tight is that?

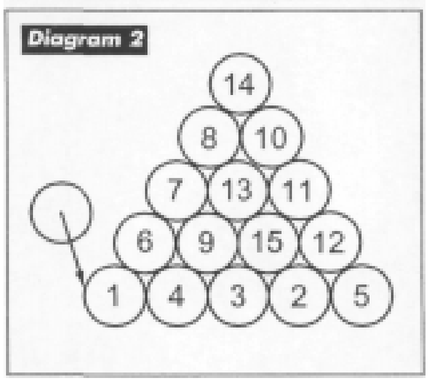
It is not theoretically possible to freeze all the balls in a rack. Here, we're talking about real pool balls that are all slightly different sizes. A new set of good balls will be the same diameter (and round) within one thousandth of an inch. The rules permit five times that deviation in each ball. With real balls, it is usually impossible to get everything frozen. Start with the 9 ball in a 9-ball rack. Assemble the rack by putting the 9 in position, and then freezing the 2 ball to its side. Freeze the 3 ball to those two, and so on around the 9, forming a ring of six balls with the 9 in the middle, as shown in **Diagram 1.** With the addition of each ball, there is no choice about where to put it, since it must be frozen to the two other balls. Suppose the 7 ball is a little small, but all the other balls are perfect. The result is as shown. The 7 can be frozen to the 9 and 2, or the 9 and 6, but it cannot be frozen to all three of its neighbors.

Suppose the 7 was larger than the other balls. Then the hole the 7 is supposed to fit in would be too small, and while you could freeze it to both the 6 and 2 balls, it could not also touch the 9 without forcing some ball away from the 9.

You complete the rack by adding the 1 ball and the 8 ball at top and bottom, and both of those can be frozen easily to the 6-7 and the 3-4, respectively. This means that for any normal set of pool balls, it is possible to rack nine balls with only one gap, and because balls are never exactly the same size, it is almost certain that there will be one gap among the balls around the 9. If there are two gaps, the rack could be better, and it is reasonable to ask the racker to try again.

In other games, the number of gaps varies. At 6-ball, you can obviously always do a perfect rack: start with a triangle of three balls, and then put the "corners" on — everything can be frozen. At the 15-ball games, you can work from our 9-ball rack by putting three-ball "corners" against the 8-4-5 and the 8-3-2 sides. With a little thought, it's clear that each set of three balls might require one additional gap, giving three required gaps in any 15-ball rack.





Pat Fleming has pointed out a way to get rid of these "necessary" gaps that uses the fact that most pool balls aren't round. On many sets of old balls, the "eyes" of the balls — where the numbers are — bulge out. In our example above, you might make the 7 ball "wider" by rotating it until its eyes are against the 6 and 2 balls. If that doesn't quite close the gap, you could rotate the eyes on the other balls into service. This is all a little far-fetched, but it's something to keep in mind if you just can't get a normal rack tight.

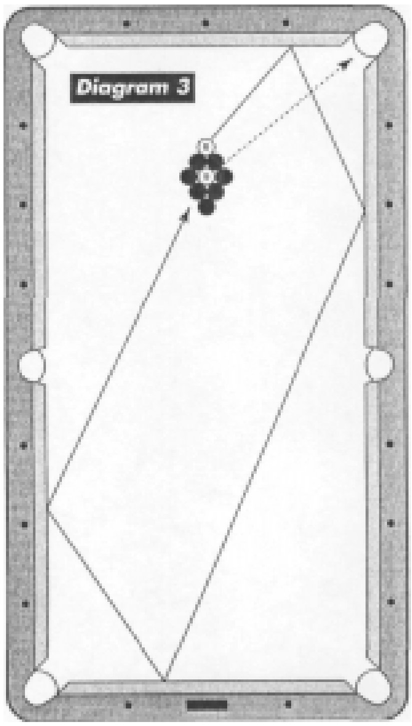
Until the recent introduction of the Sardo rack, the chance of getting a rack with minimum gaps by using a wooden triangle was nil. On new cloth and with a good set of balls, you can get close, and players often remark on how well the balls break under such conditions. As the cloth wears and gets small craters in the rack area, and especially as the rackers move the rack around and spread out the craters, the chances get slim, and soon Slim leaves town.

Several things help the Sardo rack produce nearly perfect racks. In tournaments, the cloth is marked to show exactly where to put the edges of the rack, so the chance of "crater spreading" is reduced. Compared to the typical wood triangle, it is far more accurate mechanically — just think about how often you have to turn an standard triangle to find the one good corner. Finally, the top part of the rack that comes down to position the balls pushes them gently together, rather than forcing them into specific positions, so any mismatched ball is accommodated as well as possible.

What happens differently with a near-perfect rack? At 14.1, the ideal break is for the two corner balls (the 1 and 5 in **Diagram** 2) to go to cushions and return to the rack with no other ball moving — a perfect rerack. With a good rack, this shot is impossible. As shown, the cue ball will hit the 1 ball into the 4. The 4 will move to the right and it will contact both the 9 and 3. The energy transmitted to the 9 will eventually emerge with the 10, 14 and 11 balls leaving the rack. If you want to do the perfect 14.1 break, just leave gaps between the 4-9, 3-15 and 2-12. If those balls are frozen, extra balls are guaranteed to move.

What happens differently at 9-ball? The first thing that a lot of players noticed with the new Tight Racks is that if you find the correct spot for the cue ball, one of the wing balls (5 or 2 in Diagram 1) is almost guaranteed to go in, even with a moderate speed (and well-controlled) break shot. For at least a year, the solution in tournaments has been to move the rack position so that the nine ball rather than the one is on the spot. This makes the wing balls much harder to make, as they must be driven more through the balls behind them.

I noticed a second difference in one of Allison Fisher's matches at the Hopkins' Super Billiards Expo this year. When she broke, the 1 ball reliably found the side



pocket. Try this yourself: break from the side cushion and hit the one ball nearly full. Test two cases, one with the front six balls all frozen — it's always possible to get this — and one with the one ball slightly separated from the balls behind it. I think you'll find that a millimeter can make all the difference in the world to this shot. What was remarkable was not that Allison played the 1, since that is the most predictable ball to make with the "forward-spotting" rule in force. What caught my eye is that she played the shot at moderate speed and seemed to be playing position on the 2 ball. The routes of the other balls in the rack start to be predictable if the rack is the same every time.

A final difference at 9-ball is that the 9 almost never moves. Although the two balls in front of it will push on it, the two balls behind will take up the energy, just as for the middle ball in a three-ball combination. If the nine isn't kissed — and on many breaks it isn't — it will still be in place when the commotion dies down. This can lead to some interesting shots. At the recent Billiard Congress of America Open 9-Ball Championship at the Riviera Hotel & Casino in Las Vegas, Oliver Ortmann was playing Ernesto Dominguez, and he needed two more games for the match. On his break, the 9 stayed at home, as expected, and the back ball, shown as the 6 in Diagram 3, came four cushions directly at the 9. In a minor miracle, the 6 hit the 9 just right to send it into the corner pocket. Tough luck for Dominguez; if any ball had touched either the 6 or 9, Ortmann wouldn't be "on the hill." Ortmann broke again, and as if it were on tracks, the 6 came around four cushions, hit the waiting 9 ball, and the match was over.

If we are going to accept tight racks at 9-ball, how should the rules change? Here's one possibility for your consideration: After the break, all balls that were made will spot, and the breaker gets the next shot. A 50-mph break will no longer be useful, but the knowledge and skill to play specific position on the 1 ball will be essential. The 1 ball could go back on the spot, since it would actually be a disadvantage to make a ball on the break. I think it would be a better sort of 9-ball.

If you would like to see what a very tight rack at 9 ball plays like, send me email (jewett@netcom.com) and I will send back a "PRN" attachment that will let you make your own racking template. You will need a computer printer and a paper-hole punch.

Bob Jewett is an Advanced-level Billiard Congress of America Certified instructor and was the National Collegiate Champion in 1975.

Bob Jewett

When Spheres Collide

More here than meets the eye.

In last month's column, I mentioned in passing that pool balls compress during collisions. This seems to be contrary to what you see on the table: the balls appear to be hard, incompressible spheres. In fact, there must be some "give" to the surface, or they would not behave nearly as perfectly as they do.

In July 1998, I explained that to study a cue stick, you should think of it as small lumps of mass joined by short, stiff springs. Since the naked eye can't see the stick compressing along its length during a shot, you might conclude that the stick was perfectly stiff, did not compress, and delivered its energy through the tip to the ball nearly instantaneously. In fact, what happens is that ball pushes on the tip and compresses it, the tip pushes on and compresses the ferrule, which pushes on the shaft, which then pushes through the joint, into the butt and finally to the back end of the cue. As the ball comes off the tip, all this compression is relaxed, and the energy stored in the compression of both the tip and the stick itself is mostly released into the cue ball. I say "mostly" because both the stick and the tip are not perfectly springy. Some energy is lost into the stick/tip combination, but if there were no springiness at all, the cue ball would have only about 60% of the speed we see.

Do you remember from high school what sound waves are? They are a similar compression of the air by something vibrating. Usually the sound energy doesn't come back, but when it does, it's an echo. You can think of the compression of the stick as echoing off the back end, and in some sense doubling the speed of the cue ball. Like an echo, the compression of the stick moves with the speed of sound. Unlike the echo, the speed in the stick is not the standard speed of sound — lightning a mile away will be heard in five seconds — but is the speed of sound in the wood of the stick.

By now it should be clear that ball-ball collisions aren't as simple as they may seem on the surface. When the cue ball hits an object ball, a sequence like the one for the stick-ball begins. This is shown in **Diagram 1,** with the compression slightly exaggerated. At the first instant of contact, the cue ball is still moving forward but the object ball hasn't started to move yet. Something has to give, and what gives is the spherical shape of the balls. As they move together, flat spots develop on each one as the plastic in the contact area compresses. The cue ball continues to move forward as the compression starts to move the object ball. As the object ball picks up speed, at some point it is moving just as fast as the cue ball.

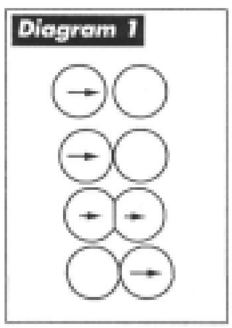


Diagram 1

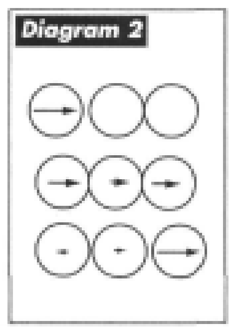


Diagram 2

This "equal-speed" point happens to be at the time of maximum compression, when the flat spot is largest, and when half of the energy of the shot is stored in the compression of the surfaces of the two balls. After this point, the compression releases like a spring, and that stored energy is put back into the object ball. If no energy is lost in the balls — and they are really quite close to perfect — the push-off of the object ball from the compression will stop the cue ball dead.

I bet you didn't know that all of that goes on when you shoot a stop.

How big is the flat spot? You can find it yourself by putting a piece of carbon paper (if you can find one) in front of an object ball and then noticing the size of the mark the cue ball leaves. It also works to use freshly waxed balls or balls with a wet film from your condensed breath. The result is that for a hard shot, the flat spot is a quarter-inch or six millimeters in diameter. How much did the surface of each ball compress during such a collision? Simple geometry says about 0.3mm or one hundredth of an inch. That's about the thickness of three sheets of typing paper.

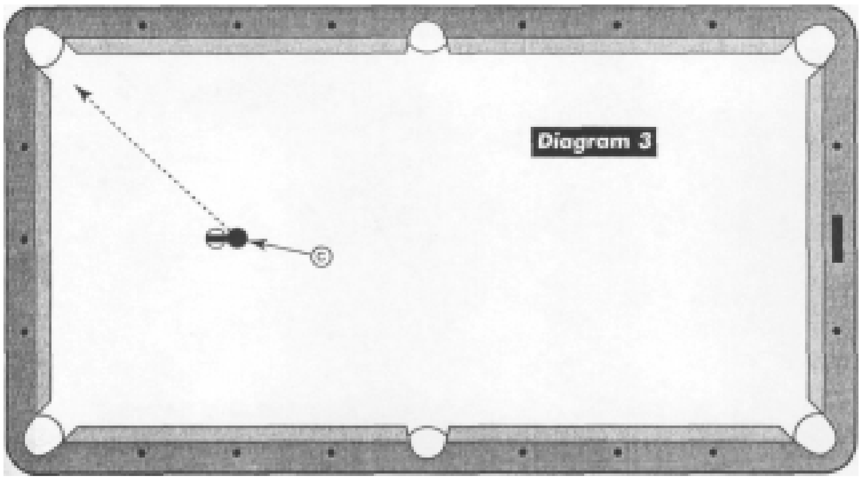
How long does this collision take? It can be measured just from the size of the flat spot and the speed of the cue ball. It has also been measured directly by Wayland Marlow in an experiment described in his book, *The Physics of Pocket Billiards.* He measured the time the balls were in contact by having them make an electrical connection (that's the hard part) and then measuring the time of the contact (that's the easy part). His typical result was 200 millionths of a second. It is important that this time is much longer than the time it takes for sound to travel from one side of the ball to the other, or just as for the cue stick, the "echo" of energy from the far side of the ball couldn't take part in the shot.

The ball-ball collision is hiding a further subtlety that can be important in play. As the balls compress together, the interaction is not like a simple spring. Instead it is a sort of compound spring, because as the flat spot gets larger, more and more surface area gets involved. This means that the "spring" gets "harder" the more the balls are compressed. For a normal cue-ball-to-object-ball collision, this makes little difference, but when another object ball is behind the first object ball, as when two balls are spotted on the long string, the exact nature of the collision becomes important.

What happens during the shot is illustrated in **Diagram** 2. This is for balls that are perfectly springy (elastic) and the prediction is a little surprising. Theory says that for perfect balls, the cue ball is expected to bounce back from the two-ball collision with some speed. For the "progressive spring," the speed back is expected to be about 8% of the incoming speed. If the balls behaved like regular springs, governed by Hooke's Law, the bounce-back is expected to be twice that large.

Why do three balls behave so much differently that two? It turns out that for just two balls, the Laws of Conservation of Energy and Momentum forbid anything except the stop shot from happening. If three balls are involved, there are many outcomes that satisfy the two Laws, and which outcome we see can only be predicted if we include the exact details of how the balls interact. The three balls must be all touching at the same time during the collision.

So, if the cue ball is expected to bounce back, how come we never see it do so? (Draw doesn't count.) The answer seems to be that enough energy is lost in the collision that the cue ball is fully stopped, but doesn't get enough push-back from the springs to get negative motion. You might try the experiment yourself with an old set of balls, and then some right out of the box.



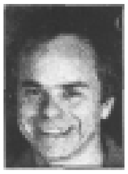
What happens to the middle ball is the useful part. It is going forward some, which is contrary to the usual teaching of "stop-shot physics." To make a shot from this for the double-spot shot, as shown in **Diagram 3,** place the cue ball a little off line, and hit the front ball full. It will get some speed to the side, but will also have some speed forward, due to the "three-ball effect." If you have the right small angle, you can make the front ball in the corner pocket. This kind of shot has been described here before as the "10-times-fuller" system. The factor of 10 can be predicted from the physics. Also, since the compression length is so small (less than 0.3mm), the shot is greatly changed if the two balls that are supposed to be frozen are even the thickness of a dollar bill apart.

The compound spring law that governs spheres in collision is called Hertz' law, and it was discovered by the same physicist who discovered radio waves and whose name you see in "megahertz" and such terms. The details of the law are an active area of research, and not just on the pool table. It turns out that industrial processes which transport beads or pellets of material have lots of ball-ball collisions going on, and Hertz' Law is needed to understand them. If you have access to the Web, enter "Hertz contact law sphere" in a good search engine, and you should get plenty of equations.

If you've waded through all of this rather technical stuff, you deserve a reward. Here's an old puzzle, slightly reworded. If you get the correct answer and are the entry chosen by our autocratic judge — me — you'll get a one-year subscription to this magazine. It's better to send e-mail to jewett@sfbilliards.com, but real mail sent to *BD* in my attention is OK.

In 1887, the bright, young Mr. Hertz was walking down a street in Berlin when he heard an unfamiliar clicking sound coming from a tavern. Entering, he saw a teacher and a pupil and three ivory billiard balls. Hertz had heard of this "billiards" but had never seen a table before. The teacher shot a simple carom — with the click that had attracted Hertz — and explained the 90-degree initial carom angle. Hertz piped up, "But the angle between the paths of the balls must be less than 90 degrees." How did he know? For extra credit, what was his mistake?

Bob Jewett



Sliding Friction

How far will you slide?

It is **the** various kinds of friction that make cue sports interesting. Without rolling friction, the balls wouldn't stop until they had all found pockets. Without the friction between tip and ball, which is aided by chalk, we would have no control of spin and position. Without the friction between the balls, the dimension added by throw shots would disappear. Without ball-cushion friction, position play would be severely restricted.

Another kind of friction that is at work on every shot is sliding friction between the balls and the cloth. This was mentioned briefly in the two recent columns about calculating and plotting the speed and spin of a ball as it achieves normal rolling on the cloth. The natural state of the ball is normal rolling, because any sliding between the ball and the cloth produces a force on the ball that will tend to eliminate the sliding.

Sliding friction is harder to measure than the other kinds. Rolling friction — which causes the ball to roll to a stop — can be measured easily with a stopwatch. Friction between the balls is shown by the maximum throw angle. You can get at least a feel for friction on the cushion by the resulting angle for a cue ball with maximum spin going straight into the cushion.

The friction between ball and cloth is dynamic; it always has time as part of its measurement. An example shot of the effect is shown in Diagram 1. This standard fancy shot demonstrates how to make the cue ball curve without masse. The idea is to pocket the first object ball, and then curve around the obstacle ball without hitting the side cushion and pocket the hanger. Shoot slightly fuller than half-ball, which will allow the draw to pull the cue ball back enough.

Shown in the diagram are two curves for the cue ball's path. They represent shooting the shot at the same speed, and with the same amount of draw but with different amounts of sliding friction. If the cloth is new or the cue ball is waxed — try silicone spray if you want to do the experiment — the cue ball will take the wide course and will look as if it is moving in slow motion. If the cloth and balls are sticky, the result is the sharper, faster curve. Under sticky conditions, the shot can be fixed just by shooting harder, but that can get you into miscues, jumped balls, and other problems.

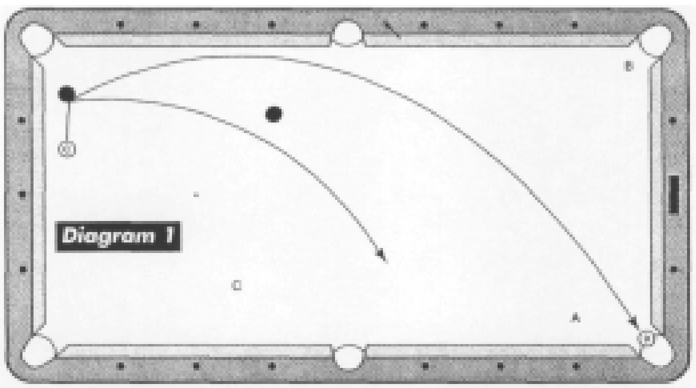


Diagram 1

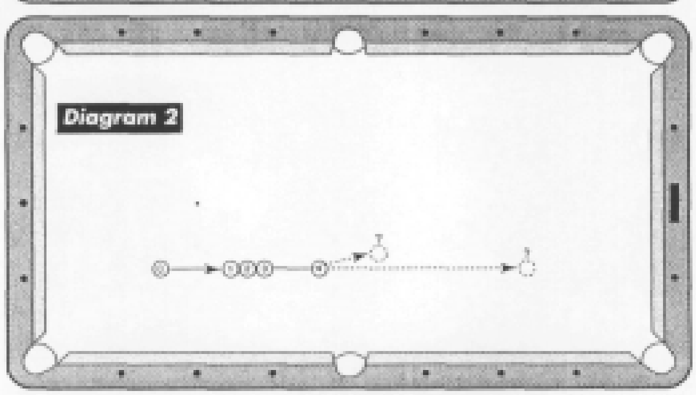


Diagram 2

Silicone spray has become a standard tool for fancy-shot artists who want to move from amazing to impossible shots. The main effect is to get much wider, slower curves with less effort. An example is a shot by Semih Sayginer in his closing exhibition at the Conlon WorldCup Tournament, July 18-23, in Las Vegas. The cue ball was at A, and the target was at about B. The actual shot was a carom shot, but it would also work as a pool shot. The cue ball massed around the obstacle ball over five diamonds away and came back to the target. With an unwaxed cue ball, the standard shot is to make just a right-angle turn from C and then go to the target at B.

Exactly how does "slipperiness" enter in? With little friction, the force on the base of the ball is less. This leads to less acceleration at each instant the rubbing is going on, so the curve happens more slowly. It also means that the spin is not being rubbed off the ball as quickly, so the curve goes on for a longer time. In some sense these two effects balance, so that in Diagram 1, the final angle that the cue ball takes is the same regardless of how much friction there is. A sharper curve for a shorter time gives the same angle.

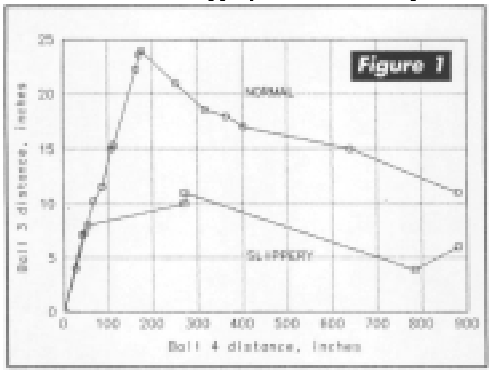
The effect is present on straight shots as well, but it is a little harder to see. The main result is that with low friction, the cue ball holds its draw for much longer. Have some fun with a friend: On a table with old cloth, secretly grease up the cue ball. Put an object ball in the jaws of a foot pocket, and challenge your friend to shoot a stop shot from behind the line. If he's got a pretty good stroke, and is calibrated for the old, sticky cloth, he's likely to draw the cue ball clear back to the kitchen. Normally, the considerable draw at the start of the shot would be worn away over the six diamonds of travel, but the silicone reduces the rubbing and holds the draw for longer.

How can we measure sliding friction? These shots give you a feel for whether a particular ball/cloth combination is more or less sticky than you're used to, but it's good to have an actual number to compare. Physics books suggest measuring sliding friction between an object and a surface below it by pulling the object sideways, and noting what fraction of its weight must be applied to keep it in steady motion. Balls tend to roll when pulled sideways, so that's not convenient. You could glue three balls together, like a mini-rack, and pull that sideways, but you would need glue, spare balls, and a string, pulley and weights to do the pulling.

Another way would be to videotape a curve shot like the one in Diagram 1, plot the result to scale along with the time of each location, and do a lot of arithmetic. A simpler way is shown in **Diagram 2.** The idea is that if you shoot the three-ball 1-2-3 combo at the 4 ball, the 3 ball will roll forward some distance after hitting the 4 ball, and that distance will tell us how much follow the 3 ball picked up on the way to the 4. If there is more sliding friction, the 3 will pick up more follow and will roll farther.

Suppose we vary the speed of this shot from very slow to fast. For the slowest shots, the 3 will just get to the 4 ball and will surely be rolling smoothly on the cloth. It will drive the 4 down the table and roll a little after it. These two distances will follow a simple rule that was covered here last December: the 4 will roll seven times as far as the three. This holds for full shots where the "cue ball" is rolling smoothly on the cloth. As the shot gets faster, there will be a point when the 3 just gets to smooth rolling on the cloth as it hits the 4. This should result in the maximum run-through of the 3, since for faster shots, it doesn't have enough time to pick up full follow. In effect, we are shooting a stop shot with the 3.

The measured result is shown in **Figure 1,** where the follow distances of the two balls are shown. For the regular case, there is a very clear peak which shows the maximum speed that still achieves smooth rolling on the 3 ball. I also tried polishing the 3 to reduce the friction, and the lower curve was the result. It shows only about half the peak run-through of the regular case, since the slippery 3 ball doesn't pick up follow as effectively.



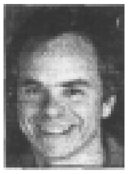
If we can figure out the speeds of the balls for these cases, it is a simple matter of algebra to figure out the friction of the cloth. The whole calculation goes roughly like this: A ball is measured to take eight seconds to roll 98 inches. This lets us calculate the speeds of the two balls, given their rolling distances; We can then calculate the speed of the balls at impact, and the speed of the 3 ball when it is struck by the 2 ball. Knowing that the distance between the 3 and 4 is 10 inches, we can calculate how much the 3 slowed in that distance due to picking up follow from the cloth. This in turn gives the sliding friction on the ball. The final result — details of the calculation available on request — is that the cloth-ball coefficient of friction is 0.25, so that the force on the ball when it is sliding is 25% of its weight. For the "slippery" case, the coefficient of friction is reduced to 70% of this value or about 0.18. These values agree well with the value that Coriolis measured over 160 years ago, of 0.20.

How can you use these ideas on the table? The main thing is to realize that on new cloth or with waxed balls, some things will change greatly. Many players like to shoot "stun run-throughs" or stop shots that don't quite stop. The success of such shots is critically dependent on how much sliding friction there is. As the weather gets humid, you will see the opposite of the slippery condition; the ball-cloth friction goes way up. In this situation, stop shots will turn into follow shots, and draw will be much harder to achieve.

Bob Jewett is a Billiard Congress of America Advanced-level instructor, and a partner in the San Francisco Billiard Academy, which has courses for beginners to instructors.

TECHTALK

Bob Jewett



Playing Games

Renew interest in your favorite game by trying a few others on for size.

Has your game reached a plateau? Do you feel like you're in a rut? What you may need is a new game.

Pool halls are largely filled with players who know only one game. If they play 8-ball, they will refuse to play 9-ball because the shots are too hard and they don't understand the safety play. If 9-ball is their game, they won't shoot straight pool because they're confused by all the choices, and of course they don't understand the safety play. If they play pool, they'll never get close to those tables across the room that are 12 feet long or don't have any pockets.

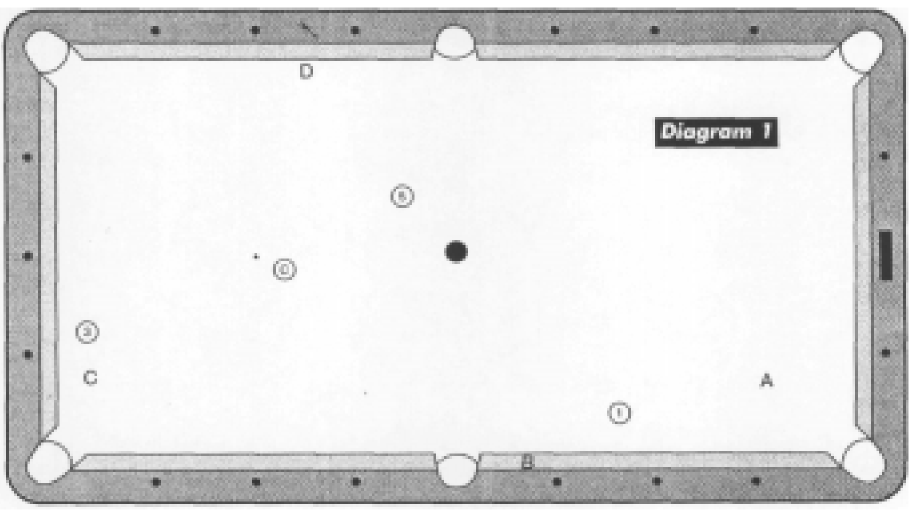
Such stick-in-the-muds never stretch their minds, never learn new techniques, and will be playing the same game in the same way in 20 years that they have for the last 10. I hope you aren't one of them.

When I first started playing, I had an ideal situation to try different games. Pool, snooker and carom tables were all available at the comfortable rate of 40 cents per hour. There were fairly good players on all of those tables — at least they were a lot better than I was — and national- or world-class players could always be seen on a trip to "The City."

Among the games that I played during my first year or so were straight pool, 6-ball, 9-ball, 8-ball, cribbage, cut-throat, partners rotation (money ball), kiss pool, call-position 14.1, and one-pocket on the pool table; snooker, golf, pink ball, and English billiards on the snooker table; and straight rail, 3-cushion and fancy shots on the carom billiard table. Bank pool, bumper pool, bottle pool, cowboy, 21-ball rotation, equal offense, Fargo, line-up, pea pool, and pin billiards I played later as the opportunities came up.

The first step to adopting a new game is to learn the rules. The easiest way is to play against someone who knows them already, or, if you're shy, to watch a game in progress. As important as the rules are the tactics and strategy. While watching an accomplished player, try to predict what he will do. If a shot really puzzles you, ask about it — most players like to show off their knowledge.

Another good source of rules, especially if you're striking out on your own, is the Billiard Congress of America rule book. It contains the rules of over 30 games and is available for less than 10 bucks, shipping included. Parts of the rules are online at the BCA Web site, or you can use a search engine such as www.google.com to find other sites.



Many games will be valuable for mastering your favorite games because they make you polish particular facets that may get neglected in the normal course of play. For example, straight-rail billiards (on the pocketless table, just make your cue ball hit both the other balls to score a point and continue shooting) will teach you how to hit the ball softly, because once all three balls are close, soft shots will tend to keep them together. Straight rail also teaches you to control all three balls on each shot, which will do wonders for both your precision-banking game and your cue ball control. Allen Hopkins and Dallas West have both recommended straight rail to improve pool skills.

If you have trouble locating a carom table, visit the United States Billiards Association Web site at www.uscarom.org for a list of all known rooms in the U.S. that have tables. The best explanation of ball-to-ball caroms is in *Daly's Billiard Book*, which was first published over 80 years ago, but gives far better general cue-wielding instruction than many modern books. An excellent modern book that covers a lot of straight rail in a few pages is Robert Byrne's *Wonderful World of Pool and Billiards.*

A game rarely seen in the U.S. but definitely worth learning is English billiards. It is played with two cue balls and a red ball like carom billiards, but a snooker table is used. Points are scored by pocketing any ball (three for the red, two for the opponent's cue ball, and three or two for your cue ball depending on whether you hit red or white first. You also get two points for making a "cannon," which is what the British call a simple carom. It's possible to score 10 points in one shot by pocketing all three balls, but this is a bad idea, as your opponent's cue ball stays off the table until his turn, and scoring with just two balls on a 12-foot table is quite a challenge. When red is pocketed (they say "potted"), it comes back to the seven or black spot (they say "billiard spot"). Many turn-of-the-century British books go into detail about the strategy and such of English Billiards, and you can often find these in on-line auctions. The full rules for the game are online at www.wpbsa.com.

A game similar to English billiards but designed for the pool table is cowboy. The game uses a shared cue ball and the 1, 3 and 5 balls. Points are scored by pocketing the object balls (score: the number on the ball) or by caroming from one object ball to another (score: one point for hitting two, two points for hitting all three). The game is to 101, with some details. You must land exactly on 90 points, or the shot that takes you over 90 is a foul. On a foul, all points of that inning are lost, but there is no other penalty. Points 91 through 100 must be scored by caroms only, and it's a foul to pocket a ball. Point 101 must be scored by a called scratch off the 1 ball. The 1 spots on the head spot, the 3 on the foot spot, and the 5 on the center spot. The full rules are in the BCA rule book, and a good search engine will find several unofficial rules sites on the Web.

In **Diagram 1** is an example position from cowboy. Your score is 85. What should you play? Fairly obvious is the 5 ball in the side which brings you to the required first step of 90 points, but you have to start planning for the carom shots that are required after 90. Play the cue ball off the end cushion to end at A, and you should have an easy carom shot from the 1 ball to the 5 when it is spotted on the center spot (where the shaded ball is). But that shouldn't be the end of your planning. Since your last 10 points must be scored by caroms, you want to gather the object balls together to make scoring easier. Play the 1 ball to hit the cushion near B and to come to rest near C. If the 5 ball after the carom ends up near its starting location, and the cue ball is near the center spot, you can shoot the 5 towards D and take the cue ball towards the 3. The 5 should bank over to join them, if your speed is correct. With all three object balls together, your run-out is assured.

The games you try should fit your skill level. Of course, if a game is fun, stay with it, but I'd recommend that beginners start with cowboy, cribbage and straight rail. If you've never run out a rack of 9-ball, why not play 6-ball instead? When I first played, 6-ball was the rotation game of choice, while 9-ball was considered too hard for most players in the room.

Advanced players should try more challenging games such as snooker, 3-cushion, bank pool and one-pocket. These will in turn help you work on pocketing accuracy, cue-ball control with spin, cushion reaction and precise speed control.

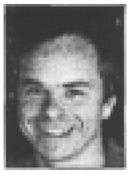
Good books are readily available for most games — does anyone know of a good one on bank pool? Byrne covers many "alternative" games in *Wonderful World* as well as his *Advanced Technique* book, and his *Standard* book is the best available on 3-cushion billiards. George Fels and Jack Koehler each have two or three books in print on strategies and techniques.

If you have a favorite "other" game you would like to see discussed, please drop me a line in care of this magazine.

In the August issue, I proposed a puzzler involving Herr Hertz and billiard-ball kiss angles. A billiard instructor was telling a student that the angle is a right angle or 90 degrees, and Hertz stated correctly that it is less. The first question was: how did Hertz know that the kiss line is less than 90 degrees? The big hint here was that Hertz was drawn into to the room by the clicking of the balls and didn't even see the collision. That sound is energy being lost in the collision, and from George McBane's guest column last February you know that lost energy means the angle between the cue ball and the object ball will be less than the ideal 90 degrees. The second question asked what Hertz' error was. The answer to that is that he should not have corrected the instructor in front of the student. Of the correct answers, Anthony DeAngelo had the most complete response, so he'll be getting a year's subscription to *Billiards Digest.*

Bob Jewett is a Billiard Congress of America Advanced-level instructor, and a partner in the San Francisco Billiard Academy, which has courses for beginners to instructors.

Bob Jewett



Round-Robin Formats

A simple alternative to double elimination.

Do you enjoy playing in double-elimination format tournaments? If you're like me, you find them torture. If you lose your first match, you have to win twice as many matches as the guy who beat you in order to finish in the same spot. How can that be fair?

Round-robin is an alternative format that solves many of the problems with "DE." It was the most popular championship format for many years, and was only displaced when tournaments started having much larger fields. Even with a large field, it is possible to have a modified round-robin that lets most of the players play more games, and is fairer in the selection of who advances.

In the basic round-robin tournament, everyone plays everyone else once. This is a standard arrangement for most league play. A main problem is to construct a schedule. There are programs and pamphlets for this, but it is very easy to do by hand. For example, suppose we have eight players, or teams, numbered 1 through 8. Write these down in two rows like this:

1 3 4 5
2 8 7 6

Pair these by columns to find the first-round matches: 1-2, 3-8, 4-7, 5-6. Ideally, all these matches happen at the same time. Now here's the tricky part. Keeping the " 1 " in its place, rotate all the rest counterclockwise:

1 4 5 6
3 2 8 7

The numbers on the top row moved to the left and the numbers on the bottom row moved to the right, giving the second-round matches: 1-3, 2-4, 5-8, 6-7. Continue this until you have seven rounds. Since each player plays everyone else, the number of rounds in a round-robin will always be one less than the number of players.

This method of "construction by rotation" works for any even number of players. If you have an odd number of players, just insert an extra player named "Bye" and you're back to the even case. Bye's opponent gets to sit out that round. There will be as many rounds as there are real players in this case.

If you work through the above example, you'll see that Player l's opponents in each round are in numerical order. It may be that it is better to have a different order. The usual problem that comes up is that if two friends are matched up in a late round, they may decide who should win to have the best chance to take first place. Suppose Andy and Bill are buddies, and when they play each other, Andy has a 4-0 record and Bill is 2-2. There is a temptation for Bill not to shoot his best so that Andy can advance to 5-0 and have a lock on a major prize. To avoid this problem, you can invoke the "brother-in-law" rule: matches between friends/cousins/road partners will be in the early rounds. To accomplish this, simply rearrange the order of the rounds, or assign the names to the initial numbers to put all of the buddy-buddy matches in the first round or two.

Figure 1

	A	B	C	D	E	F	W-L
Andy			W	W	W	W	4-0
Bill			W	W	2	3	2-2
Carl	3	1			3	2	0-4
Dave	3	2			3	0	0-4
Earl	0	W	W	W			3-1
Fiona	2	W	W	W			3-1

The results are usually shown on a special round-robin chart. **Figure 1** shows the partial results of a six-player tournament. The players' names are entered on the left side and across the top (perhaps abbreviated). The entries in the grid show the match scores for the play so far in this race-to-four event. For example, Andy has four wins on his row from his matches, marked as Ws across. To find out the scores of his opponents in those matches, just read down the "A" column to see, for example, that Carl won three games against Andy.

There are three matches left, Andy-Bill, Carl-Dave and Earl-Fiona. At this point in the tournament, the spectators will be figuring out all the possibilities. If Andy wins, he has first place for sure, but if he loses he'll be tied with either Earl or Fiona, because one of them has to win and will also have a 4-1 record.

The tournament director better still have the paper he read from at the start of the tournament that describes the tie-breaking criteria. If Andy loses and Earl wins to tie him with a 4-1 record, there are two common ways to decide first place. One is by a playoff, but often there is no time for that. Alternatively, a two-way tie can be decided by the match that the two players played. Since Andy beat Earl earlier, he would get first and Earl would get second.

Other ways to decide ties include total points scored, points allowed, and inning average. The actual method is not as important as having it written down and posted. Include all the criteria in order, such as head-to-head; most points scored; fewest points allowed; one-game playoff. Also, the rule for forfeits is important to set ahead of time. If a player abandons the tournament — that is, he fails to play his last several matches — it is reasonable to simply erase his entire record. If someone misses one match, assign an F for his score for zero points.

Remember the brother-in-law rule? In the tournament shown, the angles are a little different. Because Andy is guaranteed first before the final round is played, he can lose to Bill without cost. On the other hand, another win for Bill will tie him for third place with the loser of the Earl-Fiona match, and that might be worth a little more prize money.

In a league situation where one team travels and one plays at home, you also have to assign home/away for each match. Usually this can't be done perfectly, so that every team gets an equal number of home and away games, and there are never more than two homes or aways in a row for any team. If the league plays a "double round-robin," so that each match-up occurs twice, a simple rule is to play at home in the second half if you played that team away in the first half.

In some situations, it is best to arrange the rounds so that the best matches are saved for the final rounds. It helps if the relative strengths of the players are known at the start, and the players are entered into the chart in order of ability. A schedule con-

Figure 2

	1st	2nd	3rd	4th	5th	6th	7th	8th
1st		7	6	5	4	3	2	1
2nd	7		5	6	3	4	1	2
3rd	6	5		7	2	1	4	3
4th	5	6	7		1	2	3	4
5th	4	3	2	1		7	6	5
6th	3	4	1	2	7		5	6
7th	2	1	4	3	6	5		7
8th	1	2	3	4	5	6	7	

structed to "save the best for last" is shown in Figure 2. The entries in the grid are the rounds in which each match takes place. For example, the top-ranked player (1st) plays the worst player (8th) in the first round. Notice that the nominal "number one" has progressively more difficult matches in each round, until he plays the nominal number two in the seventh round. Also note that all the matches among the top four players will take place in the final three rounds (5-6-7).

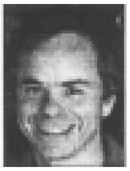
If a league plays a double round robin, the second half can be set up by Seedings from the standings after the first half, to make the final weeks of play the most important.

The main problem with round-robins is the very large number of matches for a large number of entries. Local pool tournaments commonly draw 50 players or more, and even if you had 25 tables to play on, 49 rounds would be more than most could stand. The standard way to handle this is to play "round-robins in flights." The players are divided up into smaller groups, and each group plays its own mini-round-robin. For 48 players, eight groups of six would work. Two players could advance from each group, giving 16 in the next round. At that point, everyone would have played five matches, so to save time you could switch to a single-elimination format, and there would be only four more rounds. With plenty of time, perhaps in a two-day tournament, you could instead divide the 16 players into four flights of four with one player advancing to a final round of four players. That would leave six rounds on the final day.

At the recent Conlon Worldcup 3-Cushion tournament in Las Vegas, the problem was how to accommodate 132 entries on eight tables in three days to select 12 qualifiers to advance to the main tournament with the seeded players. One way would have been to have a single-elimination tournament, but it would be brutal for the many foreign players to travel such a long way for possibly only one match. To guarantee at least two matches for everyone, the first round was set up as 48 round-robins in groups of three. Some groups had only two players, so they played each other twice. The single winner from each group then went on to two rounds of single-elimination, so no one played more than four matches in the preliminaries.

Round-robins are especially well suited to determine the best player among eight or so. They also work well for a league format with a long schedule. Even for fairly large, short tournaments, their advantage of giving everyone a reasonable amount of play makes them worth trying. A free on-line schedule planner is available at the Web site http://www.playpool.com.

Bob Jewett



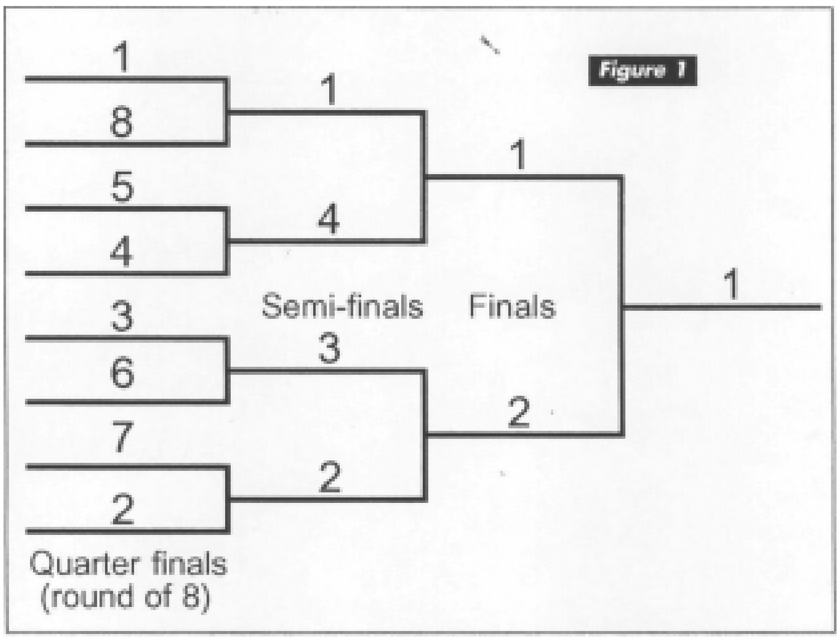
TECHTALK

Elimination Formats

More formatting alternatives for running your own tournament.

Last month, I tried to convince you to try a round-robin format for your next tournament. Round-robin is the fairest way to determine the best among a group. For best results, especially if the players are divided into preliminary flights, the relative strengths of the players should be known so that the top players can be seeded into different groups. It has the advantages of more play for most entrants and a chance to recover from a single loss, but it requires more tables and time than are often available.

When time and tables are short, an elimination tournament of some kind is better. The standard in the U.S. has been double-elimination tournaments, but there are several alternatives. This column will go over single-elimination formats of various types.



The basic idea is simple: win and you play again, lose and you go home. Figure 1 shows an eight-player chart that illustrates several important points. The first is that as you move from where the players start on the left side to the right, the number of players left is reduced by half in each round, in the progression 8-4-2-1. The math whizzes will recognize these as the powers of the number 2, which have become much more popular with the rise of computers and their binary number system. If you need more room, the next added round to the left would have 16 spots, then 32, 64, 128, and so on.

If you have a number of players that isn't a power of two, you add enough "byes" to exactly fill the chart. If you happen to play Mr. Bye in the first round, you can be pretty sure of a win — he rarely makes it to the second round.

In the example tournament, 1 beats 8 in the first round, and continues winning through the finals, where 1 beats 2.

The numbers in the diagram have a very special pattern that is important for both seeding players and placing byes. The numbers are placed starting from the 1 on the right side. Moving to the left, the 1 runs up the top of the chart. In the "finals" round, the number 2 is added next to the 1 and it runs down to the left. In the semifinals, a 4 is added next to the one and it also runs to the left. In the quarterfinals, or round of 8, an 8 is added next to the one, and if we had more rounds, they too would run down to the left. The rule is that in each round, the number next to the 1 is the number of players in that round.

One spot is left in the semifinals is next to the 2, and the obvious choice is 3, since 4 had already been placed next to the 1. This hints at the other rule for this numbering scheme: in every round, the numbers in each match add up to the same total. Thus 1+4=5 and 2+3=5. Check to see that in the quarterfinals, all the matches add up to 9. This total number is always one more than the number of players in the round.

How does seeding work? The purpose of seeding is to prevent the best players from playing each other in the early rounds. Suppose we have the defending champion and the defending runner-up in the tournament. If we place them in the number 1 and 2 spots on the chart, we have a chance to see them in the finals again. If we didn't seed them, and they were paired by chance in the first round, there would be a good chance that the best player would be quickly gone from the tournament.

Of course, you don't always know how strong the players are, and then a random draw for spots must suffice. There are also middle-strength players who will argue for random draw even if the strengths are more or less known, because they would rather have the possibility of all the champions in one part of the chart and themselves in some other part. Random draws often produce very unbalanced charts.

This numbering scheme also can be used to place byes. When placing byes, the idea is to spread them as evenly as possible through the chart. I remember a $100,000 pool tournament in the 1980s in which the byes were drawn for position just like the players, and they happened to clump together on the bottom of the chart. In that tournament, Mr. Bye played his brother, and one of them did get through to the second round. His opponent, who had played their cousin, Mr. Bye, in the first round, was very happy to see him there.

Suppose we have a tournament and six players show up. We need to fill the eight-player chart, so two byes have to be added. Just place them in the highest spots (7 and 8) in Figure 1, and have the players draw cards numbered 1 through 6 for their spots. The numbering scheme guarantees that byes will be spread out.

Homework exercise: extend the chart one round to the left for 16 players, and place five byes.

Sometimes you have to both place byes and seeded players. For this, you have to decide whether the seeded players should get a free ride in the first round. If so, just use the chart as is — the high numbers where the byes go are guaranteed to be next to the 1, 2, 3, etc. If you decide that the seeded players should not get byes — after all, they already have seeded spots — put the byes in the spots starting from half the number of spots plus one, and running up. In Figure 1, this would be 4+1=5 and 6 for two byes.

In some single-elimination tournaments, a much stronger form of seeding is used. The seeded players don't even show up for the first several rounds; they join the tournament already in progress. This is illustrated in **Figure 2.** The tournament begins with 16 weaker players who play two rounds of elimination to produce four players for the quarterfinals. Those are joined by four seeded players to bring the player count up to eight.

Figure 2

Is this a fair format? Of course not. Is it a good format? Maybe. If you want to provide both an opportunity for weaker players to participate in a top-flight event and guarantee that all the top players will be in the later rounds, this format is a good choice. You can think of it as two separate tournaments: a qualification event between 16 players with four advancing, and the main event with eight players, including four seeds.

A major advantage of single-elimination events is the small number of rounds needed to determine a champion. With 256 players and an unlimited number of tables, you need only eight rounds (256, 128, 64, 32, 16, 8, 4, 2) to determine a winner. The number of matches is also small, with only 255. (Rule: the number of matches is one less than the number of real players.) For scheduling, you also have to factor in the number of tables available, since you usually won't have 128 tables available. With 16 tables, you need 8 rounds of play just to get through the group-of-256. After that, things get easier, as you have only half as many players in each succeeding round. Software is available on the Internet to help with planning and charting.

Next time, I'll go into some other tournament formats. If you have Byrne's *Advanced Technique in Pool and Billiards*, turn to page 77 for some additional ideas.