# Physics 101 for Shooting Pool

Shooting pool is easy. Just line up and stroke the cue stick straight at the center of the cue ball for it to move on and knock the other balls into the pockets.

Some players seem to have a natural ability to pocket the balls as such, but for most of us the game is not as easy as it looks. First of all, lining up straight is not a done deal, as there is a little play in the swing by way of the elbow and shoulder joints. Straightness of the stroke actually depends on the brain sending a message to the muscles to guide the pool stick straight to the target. Hopefully the brain sends the correct message for the muscles to respond accordingly, but it is often persuaded by way of bad habits. Although practice can help us perform more admirably, it only works if we practice the right way for success.

We learn by doing. We get into the water to learn how to swim. However, some of us are afraid of drowning. Similarly some students of pool shy away from trying particular shots, as in fear they are apt to fail, because the shots are perceived as more difficult than they actually are. Therefore, in order not to drown in deep water or be ridiculed for failure, a little knowledge for direction is helpful to guide our learning by doing. The pool pros, for instance, advise us that a short, compact and smooth swing of the arm is more apt to push the pool stick straight than is a hard, jerky swing whereby the arm naturally pulls back farther for more force.

Besides learning by experience the game is a mental activity. The smart player wins by being able to execute a successful strategy. In most games, for instance, wise players examine the layout of the balls to think up a plan to best pocket them. However, the success of a plan requires an ability to execute it, and more options for a successful one are available if the player knows how to execute certain shots, as to apply spin to the cue ball for it to curve and/or push the object ball in a desired direction.

Knowing how to execute particular shots can be learned by word of mouth, from experience, or by applying the laws of physics. By the law of conservation of momentum, for instance, an elastic collision between two equal masses is such that relative motion of each mass is transferred to the other mass. There is the condition of table friction to contend with in pocket billiards, but this law also applies to pool balls in a simpler way

in that the pool balls are equal in size and weight. Thus, if you hit the cue ball hard with the pool stick, the cue ball slides on the table and stops after hitting the object ball dead on; whereas, hitting the cue ball less hard allows it to roll instead, as by allowing the friction of the table to take effect, such that the forward spin of the cue ball enables it to move forward after the head on collision with the object ball.

Accomplished pool shooters have learned from observation and experience how to predict how the balls will move on the table. The laws of physics only provide a means to learn it in more intricate detail for our experience to have more guidance.

## Stroking with Balance

Assuming the table top on which the pool balls lie is flat, smooth and level, it seems only necessary to stroke the cue stick straight for it to hit the cue ball where intended. If the cue ball is hit dead center, it should follow in the same direction the cue stick had been stroked. How easy the game would be if we could just stroke straight. However, stroking the cue stick straight is easier said than done.

One key to stroking the cue stick straight is balance. If we are off-balance, such that the swing of the arm is awkward, the stroke is more likely to be off line.

A proper stance is needed for balance. A standard one, as for a right-hander, is where the left foot is placed forward about four inches. The upper body is bent over the cue stick such that a loose tie would point directly down to it where the line of sight is with the cue stick and the direction of the stroke, and where the right arm is free to swing the stick in a slightly pendulum like motion.

The stroke is usually relatively soft and short. If stroking hard, the natural tendency is to pull the cue stick farther back, as in the manner a boxer pulling farther back, in place of a quick jab, for a knockout punch. The hard stroke tends to be jerky, such that the right shoulder and even the upper body are prone to move out of balance, causing the cue stick to slide sideways on the bridge. Balls hit hard are also more prone to bounce back out of the pocket. Therefore, if for some rare circumstance a hard stroke is required for success, take care to still maintain balance. For accuracy you must stroke hard the same way you would stroke soft.

Instead of pulling farther back for a hard stroke, concentrate more on the process of the stroke for it to be smooth instead of jerky, and use a short, compact stroke with straight forward wrist action.

Pool shooters also miss when they stroke easy. A common fault, for instance, is too much eagerness to rise up out of the stance before the stroke is completed. To sway the cue stick back and forth sideways to line up the shot is another common mistake. There are many others.

Balance also includes holding the cue stick properly. First balance it with gravity by using a finger at a fulcrum, as where the weights of the stick on both sides of the finger are equal. Next grip the thick end of the cue stick lightly with the thumb and next three fingers about three to five inches farther back from the fulcrum. That is where you want to hold it to push it forward.

The pool stick must also slide freely on another focal point that does not move out of place. A bridge is required. An eye-bridge is usually formed with the other hand, as by three fingers firmly planted on the table, with the index finger pinched against the thumb and curled above the middle finger to form an eye for the stick to slide through.

The eye-bridge works in most cases, but sometimes a V-bridge is preferred. It is formed from the eye-bridge by pushing the thumb upward against the middle knuckle of the index finger. It is used for stroking the cue ball high above center, as whenever necessary to stroke the cue ball when another ball lies in front of it, or for putting more forward spin on the cue ball than usual.

When stroking off a rail, the rail itself is used as part of a bridge with the stick sliding over it between the middle and index fingers.

A mechanical bridge is used when the cue ball is too far away for a balanced stance with a hand bridge. When using the mechanical bridge, grip the cue stick with the hand pointed upwards or sideways instead of down, just enough to allow the arm to swing most freely.

There are exceptional circumstances to consider. Suppose the cue ball and object ball are relatively close together near the far left corner pocket in which you want to pocket the object ball. Say you want to draw the cue ball back for an easy shot on the next object ball. If you use the mechanical bridge, you will need to be quick enough to pull it away before the cue ball draws back into it, which is difficult. Another way to

draw the cue ball back is to stroke downward at it below its center. In this case, assuming you are right handed, this drawback stroke is easier done by standing beside the left railing and facing more perpendicular to the stick instead of in line with it. This stance allows the right arm to swing downward more freely. In most cases, however, the stroke for the draw shot is with a normal stance and the cue stick level with the table.

Such body characteristics as height also affect the way you can stroke. For instance, if you were seven feet tall instead of only five feet, three inches, it would be easier to balance yourself by bending forward to stroke downward instead of level. Since stroking below center of the cue ball tends to lift it, stroking downward pushes it more forward instead of upward. It allows less follow through for spin, but spin is created from the push downward since the presence of the table prevents the ball from also moving downward. Less follow through on the stroke is also required when the cue ball and the object ball are close together, as too much follow through can end up stroking both balls simultaneously.

## Lining Up to Stroke

Where to aim when lining up the cue stick for a stroke depends on hand-eye coordination, meaning your hands become your eyes in response to memory. That is to say, it is not necessary to look at the cue ball while you stroke after lining up. Willie Mosconi wrote that he looked at the object ball during the stroke. In the movie The Color of Money, which is about a pool hustler, one actor (Tom Cruz) showed off by looking at another actor (Paul Newman) while pocketing a ball.

Watching the object ball fall into the pocket confirms the accuracy of the stroke, but this technique only works if you are disciplined enough to line up correctly to ensure your hand-eye coordination allows you to execute as such. A straight shot, as when the object ball is lined up with the cue ball straight to the pocket, is a telling event. If you miss straight-in shots it is likely because you do not line up properly in a balanced position for the arm to swing most freely. However, there are difficulties to overcome with angle shots as well.

A common fault associated with angle shots is a tendency to focus too much on the object ball rather than on the stroke itself. This fault occurs mostly with regard to the angle shot being perceived as difficult.

When the shooter focuses too much on the point of contact where the cue ball is to strike the object ball (as where it differs from the actual line of sight where the pool stick strikes the center of the cue ball) care must be taken that hand-eye coordination does not direct the stroke to that point of contact (as to unintentionally stroke the cue ball off center).

For hand-eye coordination not to error as such the mind further needs to fully grasp how to line up for the cue ball to cut the object ball at the correct angle.

It is obvious when the cue ball, object ball and pocket line up in a straight path, but the calculation is more involved when the straight path between the pocket and object ball are at an angle with the straight path between the object ball and the cue ball. You can illustrate this by placing an imaginary ball in front of the object ball such that they are in line with where the cue ball needs to hit the object ball. Note, as by the illustration below on the far left, the point of aim from the center of the cue ball to the point of contact is incorrect.
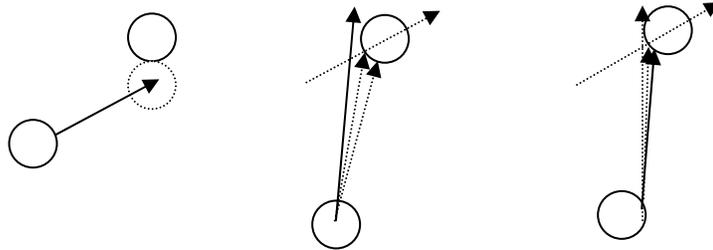


When lining up with the cue ball for it to deflect (cut) the object ball at a preferred angle, the path that the center of the cue ball lines up to take is according to the solid arrows in the illustrations above. It is, as according to the dotted arrows in the middle illustration, twice the angle from the center of the cue ball to where it lines up for a dead on collision and to where the actual contact is to take place.

There is another way to estimate the actual path for the center of the cue ball to take, as for an extreme cut of the object ball, as according to the illustration on the far right. This angle of cut is illustrated by arrows in the same manner of the middle illustration except the twice angle rule is from a ninety degree cut instead of from a head on collision.

# Kinematics

Error occurs to a degree. The greater the distance of the cue ball from the object ball, and also from the pocket, and with other balls obstructing the path between the cue ball and the object ball, there is more likelihood of missing the shot. Therefore, it is advantageous to be able to position the cue ball during a shot for an easier next shot. One way to determine where the cue ball stops on the table, for instance, is speed control. Another way is to stroke the cue ball high or low for it to either roll forward or draw back after contact with the object ball. It is also possible to have it just stop on contact with the object ball.

For these effects the law of conservation of momentum applies. Momentum is mass times velocity. Velocity is the speed of mass in a particular direction. Thus, if one mass slows down in a particular direction after a collision with another mass, the other mass acquires speed in that same direction such that its mass times its change in speed compensates for the loss of momentum of the other mass. If one mass is twice the other one, then its change in velocity from their collision is only half as much as the other. If the masses are equal, then the increase in velocity of one mass equals the decrease in velocity of the other mass.

Being pool balls are of equal mass the determination of velocity is more straight forward in that the changes in their speeds should thus be equal in opposite directions. However, the friction of the table also slows the balls. They push against the table, which pushes against Earth, which is countered by the push of the shooter in the opposite direction. The balls also tend to acquire angular momentum to avoid friction, as to roll. The exchange in velocities, therefore, will not necessarily be equal.

Let us say there is no table friction such that the cue ball does not roll; it slides on the table all the way to the object ball. In this case, no matter how fast the cue ball moves it will just stop after colliding head on with an object ball at rest. When one pool ball collides with another pool ball of the same weight and size, as in the illustration below, the linear (straight ahead) momentum (velocity times mass) of the moving ball is transferred directly to the ball with which it collides.
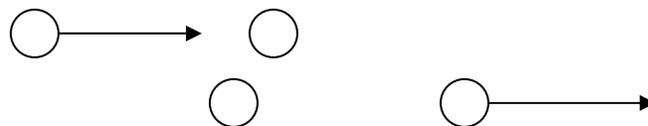
Pool tables are not frictionless. The friction of the cloth, which depends on how much it is stretched, causes sliding balls to roll, giving them angular momentum that does not transfer directly to the exchange of forward speed. The cue ball thus continues to move forward instead of stopping after a head on collision with an object ball.

One factor determining whether the cue ball slides or rolls is the amount of force put on the cue ball to cause it to plane before enough table friction is able to turn its slide into a roll. The cue ball will encounter more friction if it moves a longer distance. However, if the cue ball is hit with enough force to plane or have just enough backward spin to not roll forward before colliding head on with an object ball, then it stops and the object ball moves on in its place.

Exceptions occur when the cue ball does not hit the object ball head on. If the collision is not head on, then the cue ball will continue to move in another direction.

The initial momentum gained in any particular direction by the cue ball is compensated for by the object ball gaining the same amount of initial momentum in the opposite direction. The cue ball that slides head on into the object ball loses the same speed that the object ball acquires. The initial exchange in speeds of the two balls will also be the same if the opposite angles of their new directions are 45 degrees from the cue ball's original direction. In this case the cue ball surrenders half of its speed to the object ball. However, the cue ball moves away from the collision with greater speed than the object ball if the object ball is cut at a greater than 45 degree angle. The exact opposite occurs if the object ball is cut at an angle less than 45 degrees.

## Follow and Draw Shots

No matter how hard you hit the cue ball, the force moving the cue ball forward at a faster speed does not make it bounce either straight forward or straight backward from the object ball. Spin of the cue ball is needed instead. Hitting it easy, for instance, allows table friction to take over for it to have forward rotation by rolling. Cueing off center also causes spin. Cueing high on the cue ball adds forward spin, which converts to a faster roll. A low cue produces backward spin for the cue ball to draw back after it collides with another ball.

As already stated, the friction of the table induces forward spin on the cue ball. Even more spin can be added by cueing high and following through on the stroke with just the right amount of wrist action that can smoothly accelerate the stroke to further push the cue ball while it is in motion. This technique works for cueing low for maximum draw as well.

The amount of distance the cue ball moves straight forward or straight backward after collision depends on several factors. One is the amount of table friction it encounters, which is a measure of distance between the cue ball and the object ball. Other factors are the amount of follow through on the stroke, how hard it is hit, the smoothness of the stroke, and how much off center the stroke is on the cue ball. A higher or lower off-center stroke can result in more distance of the cue ball after collision than it does from a harder stroke. Following through on the stroke also increases spin, as it allows more force to be applied to the cue ball in more time at lower speed. Instead of pushing the cue ball faster away from the cue stick, the added force from a smother stroke at less speed converts to angular momentum of the cue ball.
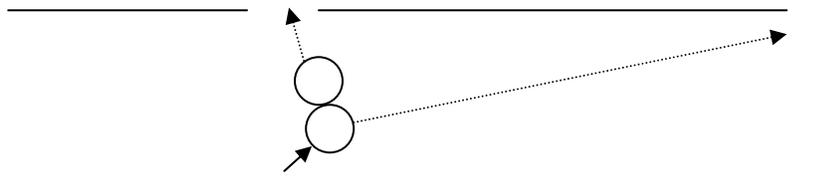
One particular application of either forward or backward spin is with regard to the avoidance of a scratch shot, as in the illustration above where the long dotted arrow indicates the cue ball is headed directly at the corner pocket. What is particularly unique about the collision, as for determining the direction of a non spinning cue ball after it hits another ball is that it then moves perpendicular to the direction given to the other ball. This result occurs no matter from what direction the cue ball hits the object ball. As in the illustration, the cue ball continues on to scratch in the corner pocket, but the scratch is avoidable either by allowing the cue ball to roll forward or by causing it to spin backwards. The backward spin opposing the cue ball's momentum causes it to reflect more to the right of the pocket whereas forward spin causes the cue ball to push on after collision to move more to the left of the pocket.

As for the application of spin, reverse spin of the cue ball is more difficult to obtain because the friction of the table counters it whereas forward spin encounters hardly any frictional resistance. Moreover, more distance means more table friction. If there is relatively little distance between the cue ball and the object ball, for instance, then a soft stroke of lower English works for either stopping the cue ball or drawing it back from impact with the object ball. However, if the distance between the cue ball and the object ball is relatively great, then the cue ball needs to be stroked with more authority.

The amount of distance between the cue ball and the object ball thus determines the manner of stroke. When the distance is more or less in the range of about six inches, lightly tapping the cue ball nearly as low of center as possible will usually stop it on most tables. Following through on the stroke for more push for backspin, and light enough not to miscue, as to push the cue ball up off the table, results in enough backward spin to draw the cue ball back six inches or more.

For practice, place the cue ball six inches in front of the object ball. Bridge low and stroke the cue ball as low as you can with a gentle tap. Notice it stops on contact with the object ball. Try the shot again by adding follow through (which naturally results in a quicker stroke). Notice how the cue ball draws back a few inches after contact. Separate the cue ball from the object ball a little farther and notice the same stroke only results in either stopping the cue ball or not even that. A firmer stroke with more follow through is required in order not to miscue. Apply more wrist action to substantially increase the amount of draw.

The amount of separation of the cue ball from the point of impact also depends on its angle of deflection. Because not all of its non-angular momentum is transferred to the object ball when the cut is at an angle, the cue ball moves on. Backward spin of the cue ball when cutting the object ball at a 45 degree angle, for instance, will easily send the cue ball to the other end of the table, as by it obtaining roll from both its angular momentum and by it retaining half of its non-angular speed.
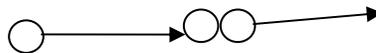
## English

English is pool language for either stroking the cue ball either left or right of center to cause it to spin either clockwise or counterclockwise. At least

four different effects occur. First, the cue ball is partly pushed to the right while it is stroked on the left. Second, it spins clockwise, which curves it left. Third, the cue ball pushes the object ball to the right when striking it with clockwise spin. Fourth, counterclockwise spin is given to the object ball for it to curve right.

The spin effect depends on several factors. For one factor, cloths on different pool tables vary. Some of them have less friction. It is easier to draw a cue ball back with less friction to overcome, but there is also less friction to cause a ball to curve. Cloths with more friction are just the opposite in effect.

Another factor is with regard to distance and speed. Since the cue ball is pushed to the right and curves to the left, the two effects tend to offset each other. However, the degree of each effect depends on how hard you stroke the cue ball and follow through on the stroke. Stroke the cue ball hard with left English and its initial push to the right continues in direction with less curvature to the left, as the ratio of forward speed to clockwise spin is greater. Stroke the cue ball easier slightly farther on the left with good follow through and it curves more to the left. More follow through also increases the amount of push one way and the amount of curving back the other way.

Since soft, slow shots curve more, whereas hard shots move more straight, distance is a compensating factor. Usually a medium stroke at a medium distance results in a successful shot even when error is made at attempting to stroke the cue ball dead center. Therefore, soft strokes are more apt to miss to the left of the target; hard strokes are more prone to miss to the right of it.

Whether to apply English often depends on where you want the cue ball to end up. The illustration above is that of a cue ball striking an object ball that is at rest against another ball. The resulting path of the front ball to the left is called throw. The throw is caused by the cue ball striking the rear ball on the right to push and spin it counterclockwise. The front ball is then pushed to the left. (It is also spun clockwise.) By this method no spin is applied to the cue ball, but the throw of the second ball can also be accomplished with clockwise spin of the cue ball instead

of it cutting the first ball on the right. Whatever method used depends on where the shooter prefers to position the cue ball for the next shot. If no clockwise spin is used, then the cue ball glances off the rear ball to move forward more to the right, whereas it stops or pushes itself left by hitting the rear ball more dead center with clockwise spin.

Balls need not be at rest touching each other for throwing one of them to the left or right. Applying English to the cue ball alone will cause it to throw an object ball one way or the other.

The amount of throw varies with the nature of the stroke. A way to execute it accurately and consistently is to acquire a feel for it. As in basketball, for instance, start with layups before trying jump shots. As in pool, a good start for reference is to line up an object ball with the cue ball with them about two or three feet apart from each other about three to five inches from an end rail. If the end rail is to the left of the shot, follow through firmly on a stroke with right English for counterclockwise spin on the cue ball, aiming for the cue ball to hit the object ball head on, as to send it directly to the side rail if no spin was applied to the cue ball. Notice instead the spin of the cue ball throws the object ball to the left into the corner pocket; that is, if an adequate amount of spin is applied to the cue ball and if the stroke is not too hard to push it too much to the right.

The amount of throw depends on the amount of spin the cue ball has in ratio to its forward speed, and the amount of spin depends on the follow through of the stroke and how much off center the cue ball is stroked. Varying them and the angle of the object ball will gives you a measure of the different effects with regard to how much spin you can apply to particular strokes of various speeds used in various situations. Continual application of this knowledge embedded in memory should make it easier to do as time permits.

Although the application of English is complex, its knowledge can actually simplify the game. If another ball is slightly blocking the straight path of the cue ball from pocketing an object ball, for instance, then it is only necessary to stroke the cue ball slightly off center to make the shot. English thus makes an easy shot out of what less knowledgeable players regard as an impossible shot to make.

# Banking

As in the illustration below, pocket billiard tables have six pockets. There is one at each corner of the table. Two more pockets are opposite each other midway between the end rails and along the side rails such that a line from the center of one side pocket to that of the other divides the table into two squares. Three dots lie between pockets. The dots along with the centers of each pocket are evenly spaced.
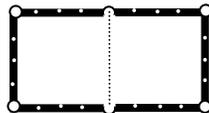


These dots can be used to calculate the path of a bank shot. If no clockwise or counterclockwise spin is given to the ball banking off a rail, then the paths to and from the rail include a perfect V.  By perfect V, it is meant distances to and from the rail are the same from a line extending perpendicular from the rail where the ball hits. The smaller inverted V in the imaginary triangle of the illustration below, for instance, is simply the part of a larger, inverted V between the other rail and a parallel line through the ball being banked.
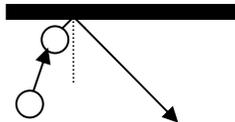


In this illustration the smaller V and its extension to the pocket on the other side of the table can be estimated in some cases. In other cases the dots can be used for convenience. For instance, since a center dot on one side of the table is half way between a corner and side pocket, the direct paths from it to the opposite side and corner pockets on the other side of the table form a perfect V. This imaginary V lines up a bank shot in either the side or corner pocket for a ball anywhere in the path.

Not any ball to be banked lines up directly with the dots, but the perfect V rule still applies. Simply count the number of dots necessary for a large V to extend to a pocket in order to estimate where the vortex and other side of the V must be.

Corner banks are similar but more extensive. Perfect Vs occur on each rail a ball banks off of. After it banks off three rails and crosses paths with its initial direction, a parallelogram if formed, as illustrated below.
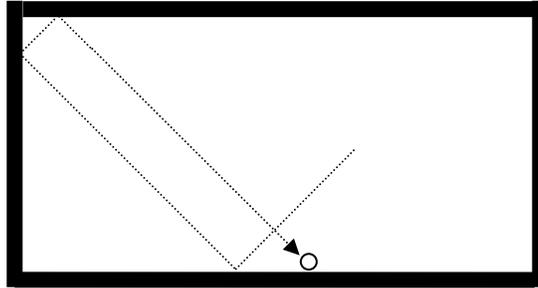
      The particular parallelogram in the above illustration is a rectangle where all paths change 90 degrees, as they angle 45 degrees toward and away each rail they bounce off of. The vertexes of the rectangle close to a corner pocket are therefore of equal distance from the pocket. However, where the ball hits the next rail depends on which rail it hits first. If it hits the end rail first, for instance, then it will hit on the opposite rail closer to the opposite end of the table. If it hits the side rail before it hits the end rail, it then hits the opposite side rail closer to the same end of the table.

      As indicated by the illustration, the rectangular path from a corner bank does not end up in a pocket. To bank a ball into a pocket, the two equal angles between the paths of each rail need be either greater or less than 45 degrees. A path to a pocket is thus a parallelogram that is more difficult to vision. Unfortunately the rules of pool do not allow the use of a protractor or any other measuring device.

      Even more difficult to vision is a deviant path caused by the use of English. Spin also alters an otherwise rectangular path. The path of a ball to and from a rail is only a perfect V if the ball spins neither clockwise nor counterclockwise. The spin is sometimes needed to avoid the obstruction of a perfect V by way of another ball on the table. It can also be used to obtain a better position of the cue ball after the shot.



      The above illustration is with regard to the use of English. Use left English to cut a ball to the right to bank off a rail with a vertex angle less than that of a perfect V. Use right English to cut a ball to the right to bank off a rail with a vertex angle greater than that of a perfect V.

# The Masse and Swerve

Left or right English can be used in a variety of ways to curve the cue ball around another ball, as when another ball obstructs a path straight from the cue ball to the object ball. When the other ball is closer to the object ball than to the cue ball, a swerve is preferred whereby the lower part of the cue ball is stroked with left or right English. When the cue ball and the other ball are close to each other, a masse is preferred whereby the cue ball is stroked high with left or right English.

The variety of ways to curve the cue ball is infinite, but whatever way is used needs to be used with predictable effect. Finesse with the right amount of follow through is the key. A grand masse (stroking nearly straight down) is not recommended except for extreme cases. If a lot of curvature is needed, banking the cue ball is more likely a better way for success. In most cases stroking the cue stick downward at 45 degrees or less from the horizontal can accomplish the task with accuracy.

Stroking downward on the cue ball increases the amount of spin on the cue ball, but stroking it too hard increases the ratio of its forward speed to its curvature. Thus stroking the cue ball hard with left English causes the cue ball to stay right whereas stroking the cue ball softly with left English causes the cue ball to curve more left. Following through on the shot also produces both more spin and more push on the cue ball to the left or right.

The process is complex, but it is possible to successfully estimate the results by using an obstruction ball for a guide. To pocket an object ball into a side pocket with another ball slightly in the way, use the other ball for a guide. Its distances from the cue ball and object ball determine whether the cue is to be stroked high or low. The amount of obstruction also determines the amount of curvature and how much angle the stroke needs to be from the horizontal.

To gain a feel for it, line the stroke up for the cue ball to hit the object ball dead center as if the guide ball is not in the way. Stroke down on the cue ball at a 45 degree angle or less, depending on the particular arrangement of the balls, and follow through on the stroke to push the cue ball enough to the right for it to miss the guide ball. (Note: If you line up to miss the guide ball, then much more curve of the cue ball is needed

for it to hit the object ball where intended.) If you did not stroke it too hard, then the spin given to it will bring it back the other way.

The success of the shot depends on how skillful you are and the margin of error. If the object ball was close to the pocket with a lot of room for error, then even the beginner is apt to be successful. Start with easy shots, as was previously suggested for throw. The throw is still part of the equation, as clockwise spin on the cue ball curves it left and further pushes the object ball right. Far less curve is therefore needed in pushing the cue ball around the guide ball, as to the right, and the push of the cue ball on the object ball also to the right.

Where to hit the cue ball depends on how far away the guide ball is from it. Stroking the cue ball high and left above center pushes it to the right and curves it more immediate to the left than does stroking the cue ball low and left of center. Even though the results also depend on how hard the cue ball is stroked and the angle from the horizontal at which it is stroked, more resistance to table friction is given to the cue ball if it is stroked low and left of center. It curves more while slowing to result in a swerve or hook. Therefore, if the guide ball is far away from the cue ball and relatively close to the object ball, then cue low. If it is close to the cue ball and relatively far away from the object ball, then cue high. If the distances of the guide ball from the cue ball and the object ball are nearly equal, then the cue ball should be hit near center.

The angle of the stroke from the horizontal also depends on how far apart the balls are as well as how hard the cue ball needs to be hit for enough curvature and force for it to pocket the object ball. If the object ball and the cue ball are both only a foot away from the guide ball, for instance, a steeper angle may be needed to obtain a greater ratio of spin to forward speed than would be if the object ball and/or the cue ball is farther away from the guide ball. If the guide ball is closer to the object ball, stroking the cue ball farther below center is preferred. If more curvature is needed, stroke down at a steeper angle for a slower forward role with more spin while aiming to miss the guide ball completely.

If just a slight amount of curvature is needed, stroke the cue stick nearly level with just enough English to allow the spin of the cue ball to slightly curve around the guide ball to slightly throw the object ball. Using

just enough follow through with either high or low English to position the cue ball where you want it for you next shot is also wise.
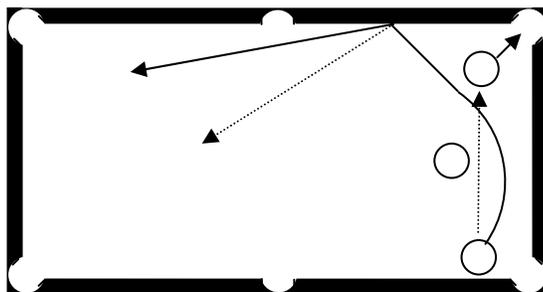


An example of particular situation for successfully curving the cue ball with ease is with regard to an object ball close to a corner pocket, as illustrated above (with oversized pool balls), such that the straight path between it and the cue ball is parallel to the end rail. Stroking the center of the cue ball with left English, as with good follow through, pushes it to the right. The clockwise spin of the cue ball curves it to the left and throws the object ball to the right into the corner pocket. In addition, the cue ball spins off the side rail more to the left.

Remember, hitting the ball either too hard or too soft does not work. As for the exact firmness by which it should be stroked, the know-how is learned from experience and a simple feel of the game.

One more effect to consider is spin given to the object ball by way of the cue ball's spin. Although the curved path of the object ball is slight in comparison, it is still part of the equation, as illustrated below.
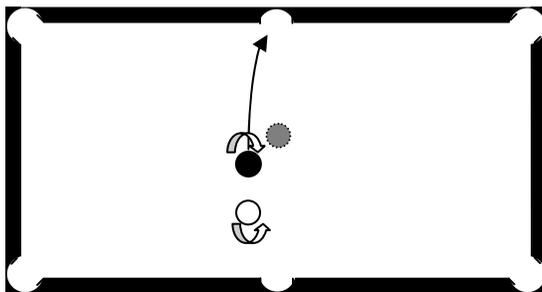


To determine how to apply effective spin to the object ball, place it and the cue ball in well marked positions on the table in order that the exact shot can be repeated. Softly stroke the cue ball with maximum spin

for it to throw the object ball enough to barely pocket it. Repeat the shot exactly as before with another ball placed close to the object ball slightly in the way of a straight path to the pocket. The other ball being in the way confirms the curvature of the path. The experiment itself also serves as a learning guide for use in a game situation if it ever comes up as such.

Although these effects are complex and require a feel, as memory from our subconscious, its knowledge can determine success if applied in the right situation. If an obstruction ball, for instance, is only slightly in the way of pocketing the object ball, only a soft shot with just a little right English is apt to be enough to slightly curve the cue ball and have it throw the object ball only enough to pocket it. An impossible shot to other pool players thus becomes an easy make for more knowledgeable players.