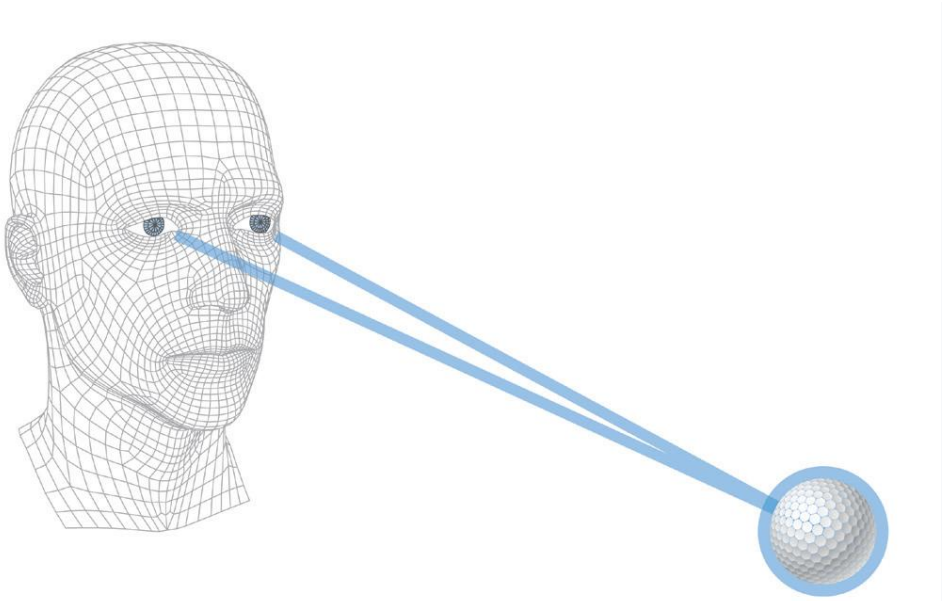
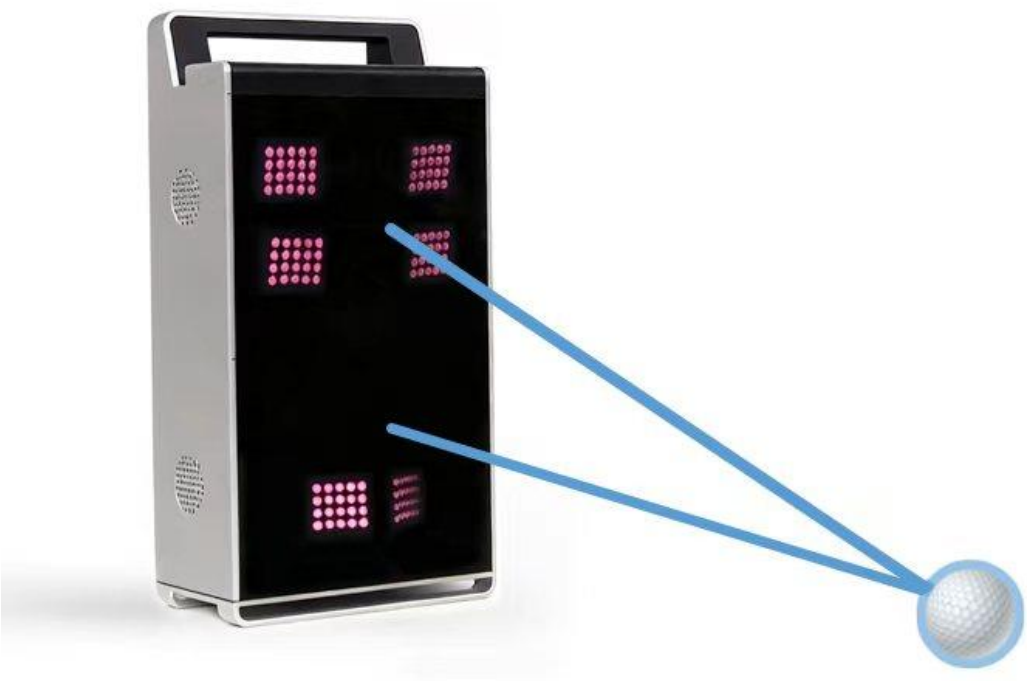
Golf Swing Parameter Guide

1. Overview

1.1 Measurement Principle

iTrack uses stereoscopic vision technology to analyze and calculate the motion data of the ball at the moment of takeoff. Stereoscopic vision borrows from the principle of "parallax" in human vision, meaning that the left and right eyes perceive a particular object differently in the real world. Our brains utilize this difference to distinguish the distance of objects. Therefore, like human vision, a stereoscopic vision system requires the support of two (or more) cameras to achieve three-dimensional (3D) reconstruction. In CaseVision's iTrack detection technology, the "two eyes" are two high-speed cameras that simultaneously capture images of the ball at the moment of takeoff at high speed. These images are then reconstructed into a 3D reality, analyzed, and calculated to obtain the necessary data.





As the ball passes through the launch detection window, these high-speed cameras capture multiple frames of images from slightly different angles. Once the images are captured, iTrack's built-in high-performance computing hardware uses stereo machine vision algorithms to analyze and process the images, calculating ball flight data and clubface data.

1.2 The Meaning of Positive and Negative Signs in Data

In data related to the flight or clubhead movement of a golf ball, we often see numbers with positive and negative signs. Here's an explanation of the meaning of these signs: the positive and negative signs represent direction. As shown in the diagram, for movement on a horizontal plane, with the target line as a reference, the direction away from the swinger is positive (+), while the direction closer to the swinger is negative (-). For movement on a vertical plane, positive (+) represents upward, and negative (-) represents downward.

1.3 Practice with Feedback

Simply put, practice with feedback in golf means that during practice, we need to know whether our movements match our expectations—in short, "check your expectations." When learning golf, we use different types of feedback to check the different stages of the swing. Feedback can take many forms, including: your coach, training aids, mirrors, Trackman, BodiTrak, slow-motion videos, and almost countless others.

We need objective feedback either from a device or from an experienced coach who tells us whether our movements are exactly what they want to teach us. This feedback is obviously crucial; it prevents us from repeatedly performing incorrect movements and forming a memory of those incorrect movements—in other words, it prevents us from practicing "wrong." A prime example: a friend, while learning golf, would almost have the clubhead pointing to the ground at the top of his backswing — a severe overswing. The coach pointed out his mistake, and he realized it himself, so he tried to correct it, attempting to avoid overswing. However, without a feedback system, as he practiced repeatedly, he didn't realize that his supposed corrections were essentially repeating his original errors. His repeated attempts to "avoid overswing" weren't significantly different from his original backswing. Examples like this abound. He might say, "Okay, coach, I understand. I'll show you how to avoid overswing," and then, at the top, the clubhead still drops. What does he need then? He needs our iSwingMirror. With each swing, the real-time replay provides direct feedback on

whether his backswing is what he wants. Many of us think that finding a coach is about learning new things, but that's not all. After learning, you need an experienced coach to supervise your practice. Of course, regarding overswing, you can find anyone, even someone who doesn't know anything about golf, and tell them your target backswing position. If you overswing, they can provide feedback. However, this doesn't mean anyone can act as feedback. More complex and coordinated movements—that is, a series of actions, such as the downswing sequence and impact zone—require guidance from an experienced coach. In the process of learning technical movements, the coach treats a particular mistake as a "result" and identifies the "cause" of that mistake through observation and analysis. This is where an experienced coach becomes even more crucial as a feedback system to help you practice. Therefore, a coach's role extends beyond simply teaching the movements; providing experienced feedback is a vital part of their job. Due to inherent weaknesses in self-awareness, most people are somewhat self-righteous, believing they are performing the movements according to their own expectations, ignoring the objective reality. They remain immersed in their self-righteousness, thinking they have corrected their mistakes, but the actual result is the repeated repetition of their errors without their awareness, leading to very slow progress and extremely low practice efficiency.

In the process of learning golf, a good coach will create a training plan for you and continuously refine it to help you improve your skills in the most effective

way. At each step of this process, they will provide you with tasks and appropriate feedback on your training. Feedback can take any form, as long as you can clearly define what behavior is correct and what is incorrect, then you can get feedback on whether your behavior is correct or not. For example, when taking off, we often expect the clubhead to cover our hands when the shaft is parallel to the ground. We can check this movement through swing video to determine if the clubhead is indeed covering your hands. If not, you can make appropriate adjustments.

When practicing alone at the driving range, it's easy to miss many things because, in most cases, the only available feedback is the ball's flight. While ball flight is an important indicator of a good shot versus a bad shot, it's not always a good one. For example, are you correctly executing the swing adjustments you're trying to make? And you can hit a good shot with poor technique, just as you can hit a bad shot with good technique. Therefore, relying solely on ball flight for feedback is insufficient. Having diverse forms and types of feedback, and having that feedback delivered instantly, is crucial for effective golf practice. Feedback allows you to accurately understand what your body, club, and ball are doing, enabling you to determine what you need to do to produce the shot you want. Real-time feedback allows you to check if you're correctly repeating your desired swing motion over and over, improving swing consistency and ensuring you're doing effective and useful swing practice.

We all hit bad shots from time to time. It's important to understand that bad shots are inevitable, even for professional golfers. Hitting a shot out of bounds or a flat shot on the fairway doesn't require a complete overhaul of your swing. Even if you've been hitting your driver well all day, and then suddenly hit a bad shot on the 12th hole, there's no reason to change your swing because it's clear you were hitting well before that. However, people often try to compensate for a bad shot by overcorrecting in the next swing, resulting in a slice going out of bounds on the 12th hole, followed by a hook shot on the next hole because they are too eager to avoid the previous slice going out of bounds. We use feedback to discover the "correct" movement and improve consistency, helping golfers build confidence on the course.

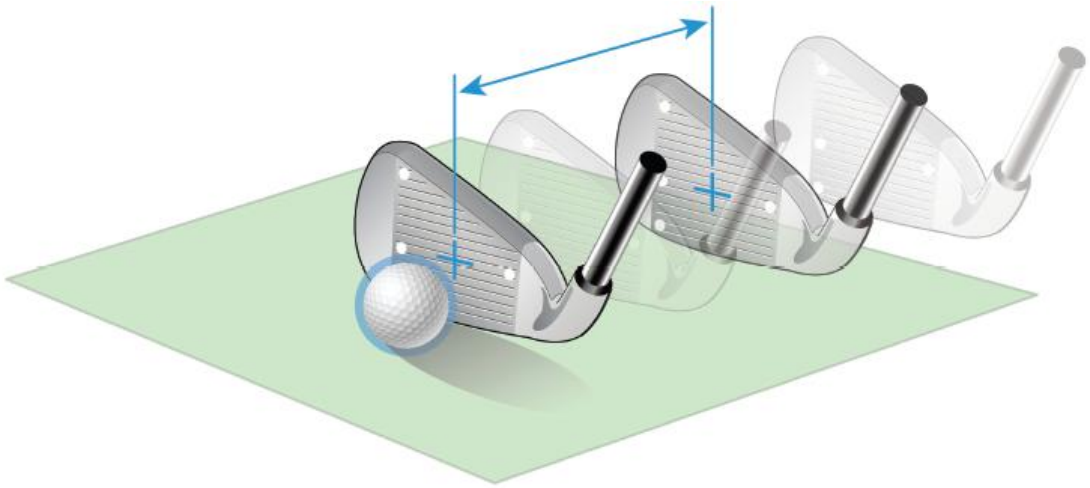
CaseVision's golf technology tools, such as iTrack (Luanch Monitor), iPutt (AR Putting Training and Entertainment System), and the iSwingMirror (Golf Swing motion capture and AI analysis) app, provide comprehensive real-time feedback for your swing instruction and practice, from ball flight data and club impact data to swing motion images and the sequence of key body parts during the swing, greatly improving your teaching and practice efficiency.

2. Club head and face Data

2.1 Club Speed

Club speed is the instantaneous velocity of the clubhead center along the

clubhead's path of motion just before impact. The faster the clubhead speed, the farther the ball travels. In fact, for a driver, every 1 mph increase in clubhead speed adds approximately 3 yards of distance. The highest recorded clubhead speed is 150 mph.



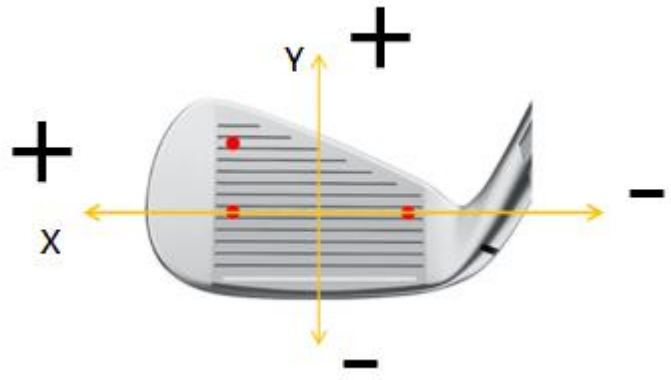
Clubhead speed indicates a player's potential distance, but distance is significantly impacted by factors such as impact point, attack angle, clubhead trajectory, and the angle of the clubface relative to the swing path. Ball speed and clubhead speed form an interesting relationship. Insufficient clubhead speed can be caused by poor weight transfer, insufficient pelvic and chest rotation, poor force sequencing, and a lack of speed training.

2.2 Impact Point Position

The impact point position of the ball on the clubface is given relative to the center of the clubface. The impact point position has a significant impact on the quality of the shot; a shot closer to the sweet spot (the area near the center of the clubface) yields the most solid shot quality.

X/Y Coordinates: X is the horizontal axis (positive values for the distance

from the center of the clubface to the toe, negative values for the distance from the center of the clubface to the heel); Y is the vertical axis (positive values for the distance from the center of the clubface to the top of the clubface, negative values for the distance from the center of the clubface to the bottom of the clubface).



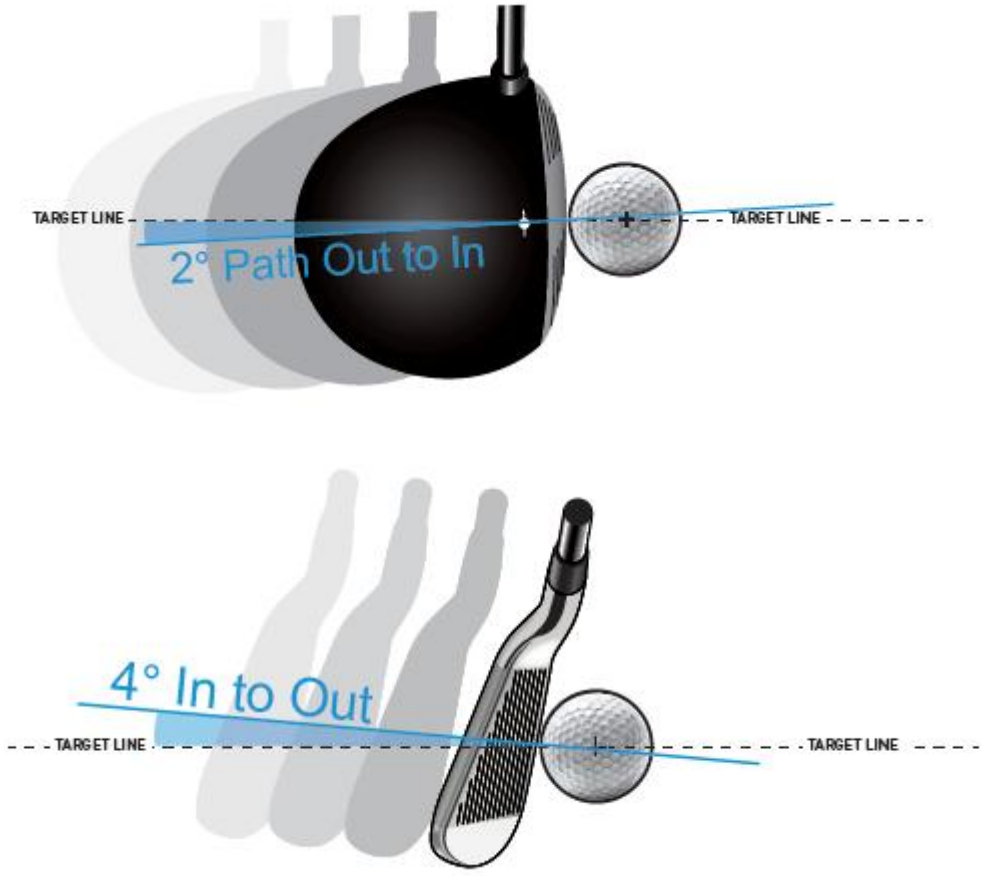
The height of the impact point is closely related to spin and clubhead speed. A high impact point reduces backspin, while a low impact point increases it. The left-right position of the impact point affects clubhead speed. When the ball hits the toe, the clubhead speed is faster than when it hits the heel. Furthermore, hitting the heel creates a cog effect, resulting in a slice (right hook), while hitting the toe creates a hook (left hook). Note that this cog effect only occurs with woods, especially drivers, increasing their forgiveness.

The biggest difference in skill between players lies in the consistency of their impact point on every shot. Statistics from professional players show a very close distribution of impact points, and in almost all cases, the impact point is closer to the geometric center of the clubface. This is especially true for clubs with a high moment of inertia (MOI), such as drivers.

One of the biggest obstacles for amateur golfers in hitting a good driver is the inconsistency of their impact point.

2.3 Club Path

The direction of movement of the geometric center of the clubhead at the moment of impact, measured in degrees. With the target line as a reference, movement from the inside out is positive (+), and movement from the outside in is negative (-).



To hit the ball straight, the clubhead path should be zero. The clubhead path affects the curvature of the ball's flight trajectory and its launch direction.

An "inside-out" clubhead path is necessary for a draw, while an "outside-in"

clubhead path is necessary for a fade. Therefore, the optimal clubhead path depends on the type of trajectory the golfer wants to achieve.

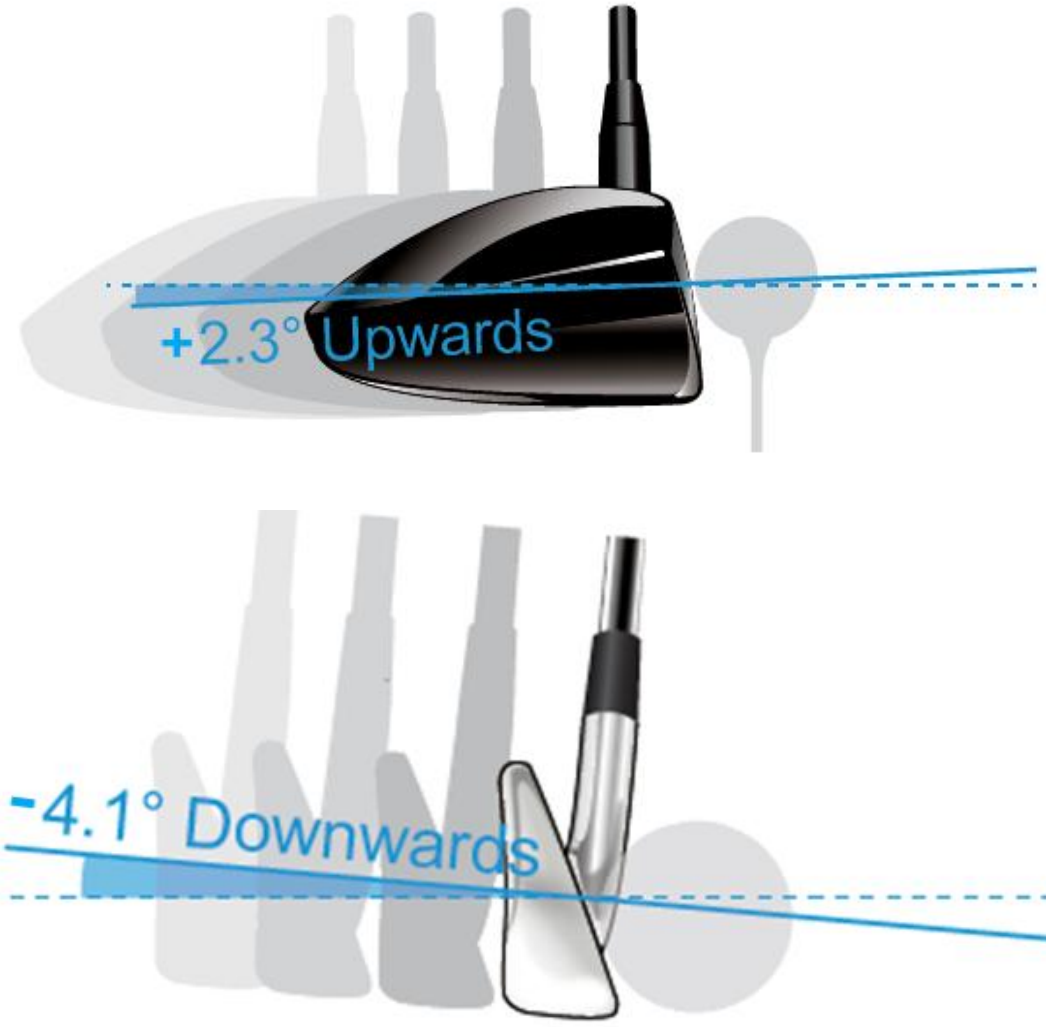
The clubhead path, along with clubface angle, lie angle, and impact point, determines the golf ball's launch direction and axis of rotation. Many factors influence a player's clubhead path, including but not limited to stance, aim, ball lie, release method, and release timing.

The clubhead path is like a fingerprint—it changes very little with each swing. Even if the club swings in an unwanted direction, it tends to be quite consistent. The clubhead path is the most telling indicator of the ball's flight shape. For example, when a golfer uses an inside-out clubhead path, they typically hit a draw. An outside-in swing does the opposite.

Probably the quickest way to change the trajectory of the club is by adjusting your stance and ball position. When you change the trajectory of one's clubhead, be sure to make corresponding and compatible changes to the loft, or the ball will not properly fly toward the target in an arc (draw or fade), but instead will slice or hook.

2.4 Attack Angle

The attack angle generally refers to the angle between the direction of the clubhead's movement and the ground (note that it is not necessarily a horizontal plane, but depends on the ball's position) at the moment of impact.



To create a "ball-first" effect, the clubhead should be struck off the ground at a negative attack angle, meaning it's a downward strike. However, golfers with slower clubhead speeds should be careful not to tilt the iron head too far downward, as this will affect ball carry distance and control at impact. To maximize distance with a driver, the attack angle must be positive, meaning it's an upward strike. Choosing a driver loft that matches your attack angle is crucial. A positive attack angle doesn't guarantee maximum distance; the right club for you is crucial.

Attack angle typically works in conjunction with dynamic loft and impact point,

primarily affecting ball spin and launch angle. Many factors influence a player's attack angle, including but not limited to ball position, secondary tilt axis (spine tilt), release type, and release timing.

A slightly upward attack angle can help increase driver distance but may compromise accuracy. If your goal is to hit the fairway, a 2-degree downward attack angle may be adequate. With irons, a shallower attack angle may be more appropriate. This is approximately 4-6 degrees downward, with the low point behind the ball.

2.5 Dynamic Loft Angle

The dynamic loft angle is the angle of the clubface at impact.

A golfer's angle of attack, shaft flex, clubhead release, clubface openness or closedness relative to the swing path, and impact point all affect the dynamic loft angle.

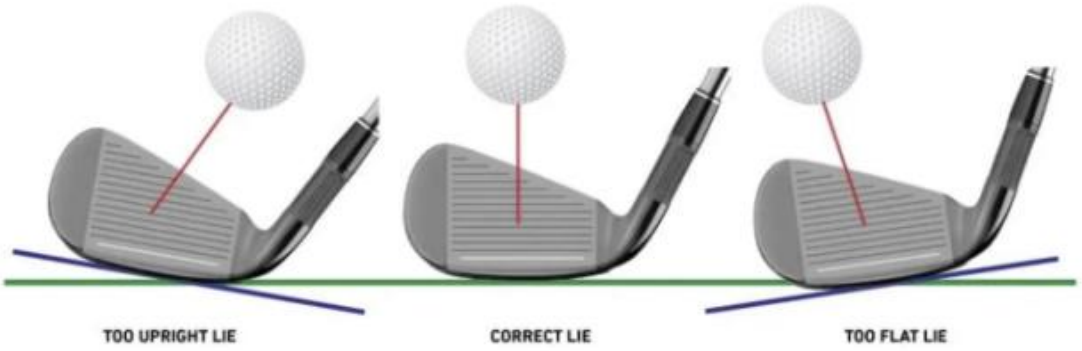
For a given clubhead speed, an appropriate dynamic loft angle is crucial for creating an optimized trajectory and maximum carry. Too much dynamic loft

angle results in excessive backspin, causing the ball to fly too high and reducing carry; too little dynamic loft angle causes the ball to fly too low, resulting in excessive roll and making distance control difficult.

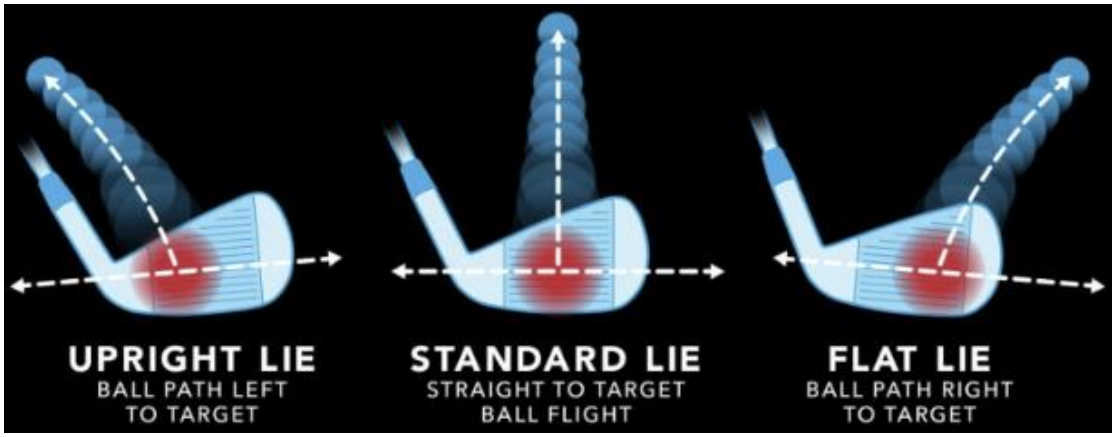
2.6 Lie Angle

The lie angle is the angle between the club and the ground:

For ease of measurement, we generally use the angle between the straight line at the bottom of the rod and the water surface as a substitute; obviously, these two angles are physically equivalent. The following diagram explains some basic concepts of the angle of repose:



Changes in the clubface angle will affect the ball's trajectory, as shown in the diagram below:



If the lie angle is too flat, the toe of the clubhead will strike the ground downwards at impact, opening up the ball and causing it to initially veer slightly to the right, creating a fading shape.

Conversely, if the lie is too upright, the heel of the clubhead will strike the ground first, causing the ball to initially close to the left, creating a hooking trajectory.

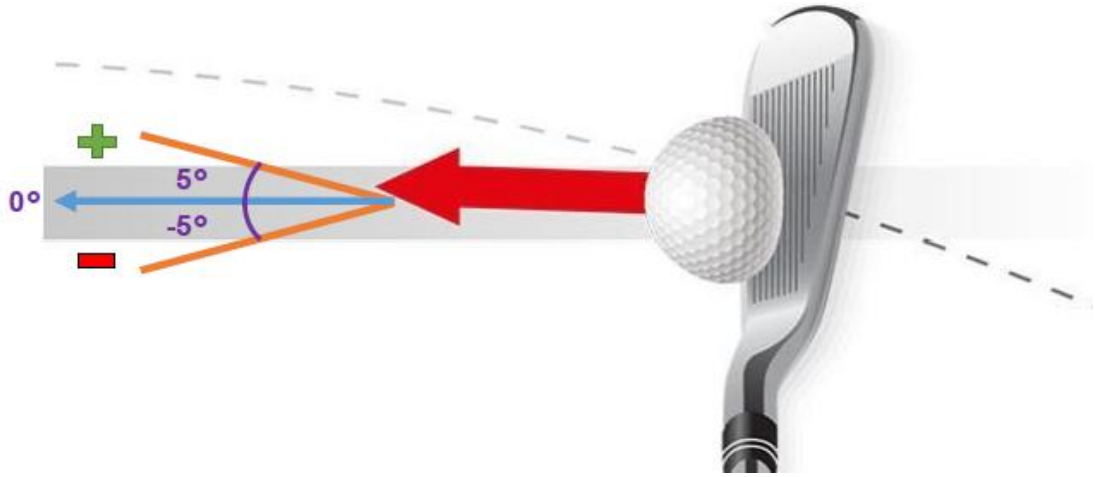
The lie angle not only affects the ball's trajectory and launch direction but also your shot consistency. Since the ball strikes towards the toes or heel, it's off-center, resulting in decreased ball speed and loss of distance.

To overcome a fade, make your lie angle more upright; conversely, to overcome

a hook, make your lie angle more flat. This will help produce straighter shots.

2.7 Face Angle

Traditionally, the face angle is measured and calculated as the angle between the sole of the clubhead and the target line. The clubface angle refers to the direction the clubface points at impact. Generally, it refers to the angle between the clubface normal and the target line (or swing path) on a horizontal plane. This is what we commonly refer to as a closed (negative) clubface, an open (positive) clubface, or a square clubface.



It is important to note that sometimes we define the clubface angle with reference to the clubhead's trajectory:

The clubface angle is a crucial parameter. The ball will fly very close to the direction the clubface (clubface angle) is pointing at impact. To hit a straight shot, the clubface angle should be 0. The optimal clubface angle depends on the type of shot the golfer wants to achieve. An open clubface results in a slice or push shot, while a closed clubface produces a hook or pull shot.

Possible reasons for an open clubface at impact: First, check if the clubface was already open at setup. Ensure the clubface is square at setup to avoid unnecessary compensation later.

The player's swing path can also cause the clubface to open at impact. If the club moves away from the body and to the outside during the backswing, resulting in an outside downswing, a slice shot will occur unless the player adjusts mid-swing. In this case, the player has to rotate their wrist at impact; otherwise, the clubface rotation is insufficient to prevent a slice.

Wrist movements during the swing can also cause clubface problems. Instructors often advise students to use larger body muscles in the swing for increased stability. When the swing relies on wrist action, if the timing is off, the player may lag at impact, resulting in an open clubface.

There are many reasons for a closed clubface at impact. The most common culprit for golfers is a wrist mishap during the downswing. This can be amplified by the setup and swing path, or it may simply be a result of the player's follow-through.

The simplest way to try and fix a clubface problem is to ensure the club remains

square at setup. A player who starts with a closed clubface is likely to maintain a closed clubface throughout the entire swing.

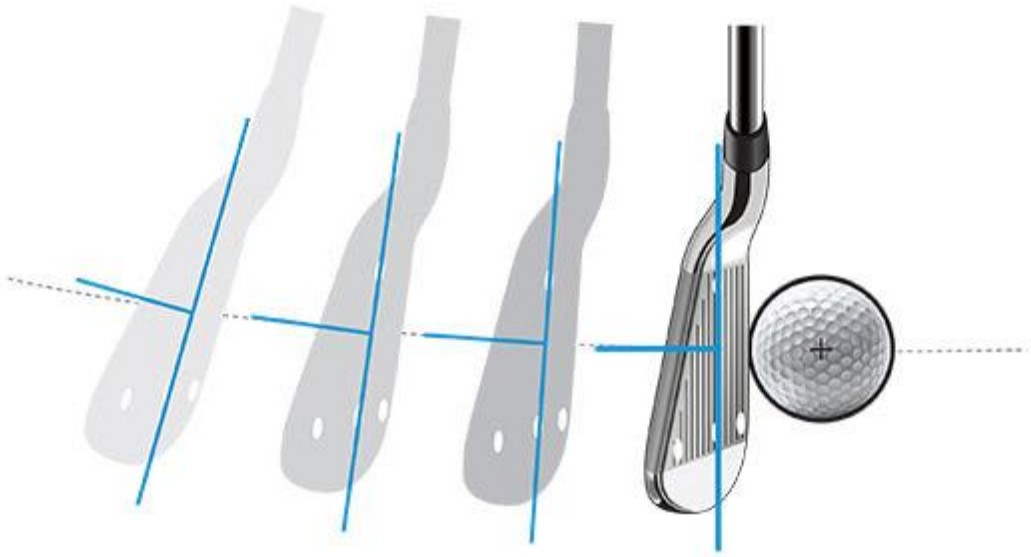
Players should also avoid making their swing too flat or using an inside-out swing path. A flat swing can be easily imagined as a lower position in the backswing around the back.

Most standard descriptions of swing path suggest that the club should be closer to the athlete's back shoulder, rather than rotating around the athlete like an Olympic thrower before release.

It should be noted that these are not universal fixes. Some players are naturally born with a flat swing path. Others use a closed clubface to compensate for the push. The only truly universal tip for keeping the clubface pointed correctly at impact is to ensure the swing is in proper tempo, meaning the player doesn't rush the swing and cause the club to lag significantly behind the movement of the torso.

2.8 Closure Rate

The closure rate is the rotational angular velocity of the pole face angle instantaneously before impact, measured in degrees per second (dps).



Closing rate (RoC) plays a crucial role in understanding how a golfer positions the clubface at impact.

RoC peaks near the impact point and typically ranges from 1800°/s to 3600°/s for any golfer, regardless of skill level. There's no right or wrong answer to this parameter; a lower value is generally preferred, but there's no real reason for it to be biased. Some argue that this parameter is primarily for assessing swing

consistency; ideally, it should be consistent across all swings.

2.9 Smash Factor

Smash factor is the ratio of ball speed to clubhead speed, representing the efficiency with which the clubhead transfers energy to the ball. A higher value indicates more energy is transferred from the clubhead, resulting in higher launch speed.

The clubface's angle relative to the path, loft angle, and impact point all affect the smoke factor. This means that hitting a slice or hook shot is unlikely to result in a high smoke factor, and clubs with large loft angles, such as wedges, are also unlikely to have a high smoke factor. This phenomenon is not difficult to understand: the larger the clubface angle relative to the path, the greater the sidespin on the ball; conversely, the larger the loft angle, the greater the backspin. Therefore, both cause more of the clubhead's energy to be converted into the ball's rotational kinetic energy, reducing the ball's translational kinetic energy, thus decreasing ball speed and impact efficiency.

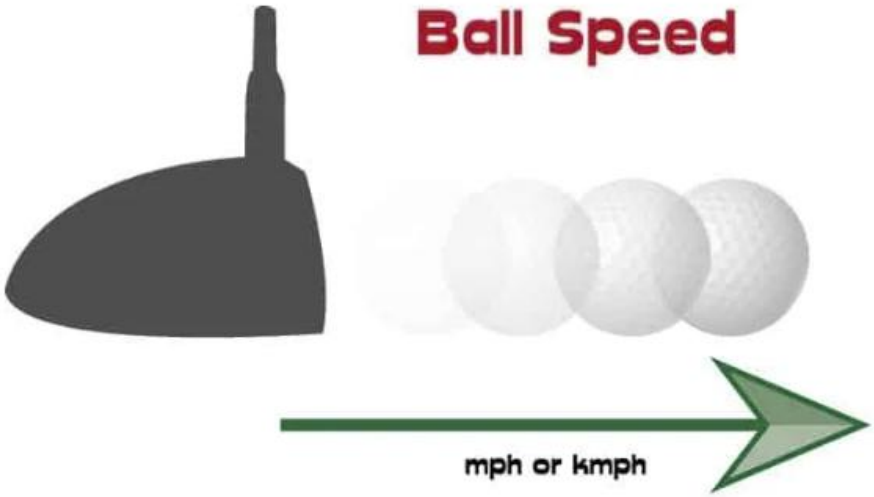
From the driver to the fairway wood to the irons, impact efficiency decreases progressively because the greater the loft angle, the lower the impact efficiency. 1.5 is almost the maximum impact efficiency.

Hitting the ball at the sweet spot yields even higher impact efficiency.

3. Ball Launch Data

3.1 Ball Speed

Ball speed refers to the initial launch speed of a golf ball after it is struck by the clubhead.



The primary factor influencing ball speed is clubhead speed, but impact point and dynamic loft angle also significantly influence ball speed.

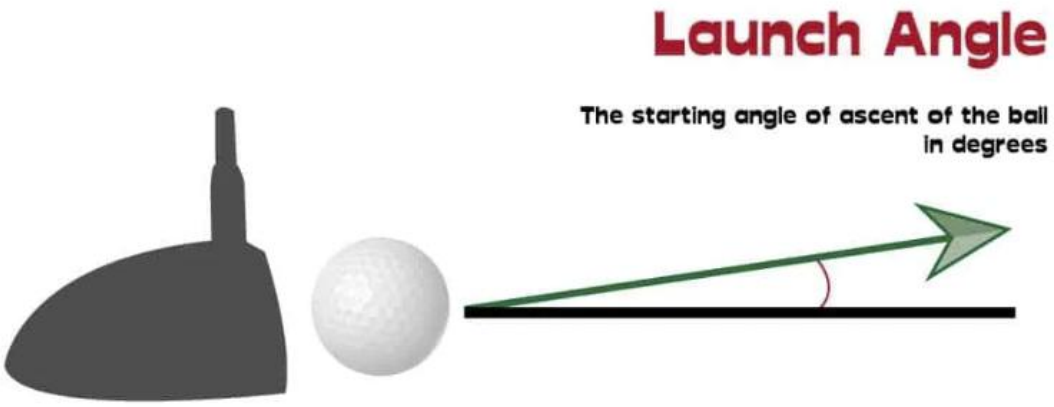
Different impact points can cause ball speed to vary by as much as 15%. Dynamic loft angle is inversely proportional to ball speed. For a given clubhead speed, increasing dynamic loft angle decreases ball speed. Swinging a 64-degree wedge at 90 mph can produce a ball speed difference of up to 45 mph compared to swinging a driver at the same speed.

Every 1 mph increase in ball speed can potentially increase your tee shot distance by 2 yards.

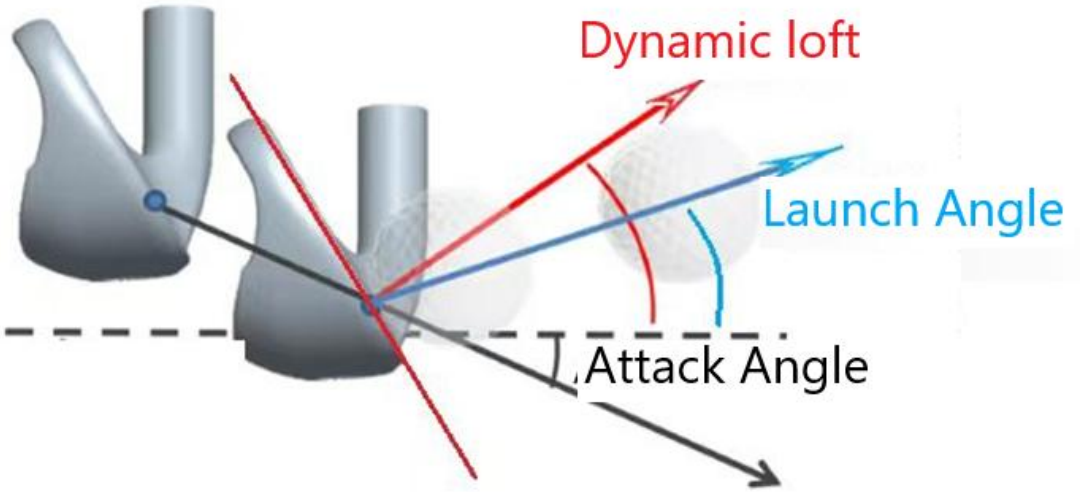
3.2 Vertical Launch Angle

The angle of the ball relative to the ground at the moment of launch. Also

known as the vertical launch angle or the pitch angle of the ball at launch, it is measured in degrees.



Launch angle affects the height and landing distance of the ball's trajectory. Most golfers initially believe that launch angle is closely related to the angle of attack, but in reality, depending on the shot type and clubhead speed, the angle of attack contributes between 17% and 37% to the launch angle. The largest contributor to the launch angle is the dynamic loft at impact, which contributes between 63% and 83%.

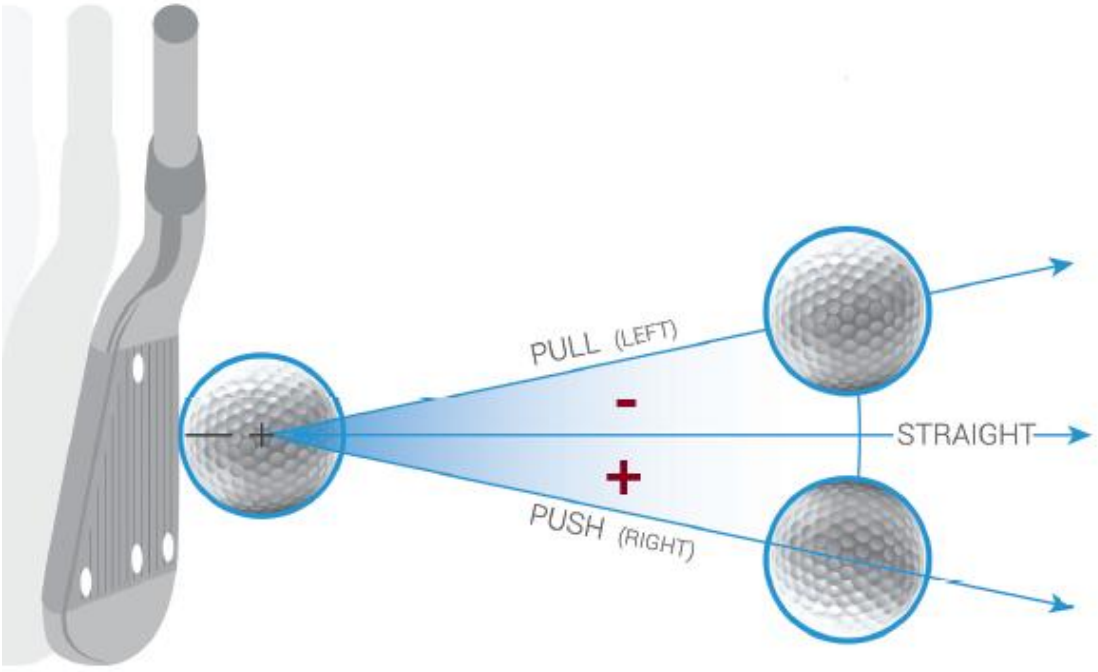


What is the optimal launch angle? We learn in physics that launching an object at a 45-degree angle will result in the farthest flight. So why don't tour players

launch at 45 degrees? The main reason is that a golf ball spins during flight, while physics textbooks refer to launching objects without spin. As mentioned earlier, a spinning ball generates lift during flight, making it fly higher. Therefore, our launch angle needs to be lower than 45 degrees to achieve the maximum flight distance.

3.3 Horizontal Launch Direction

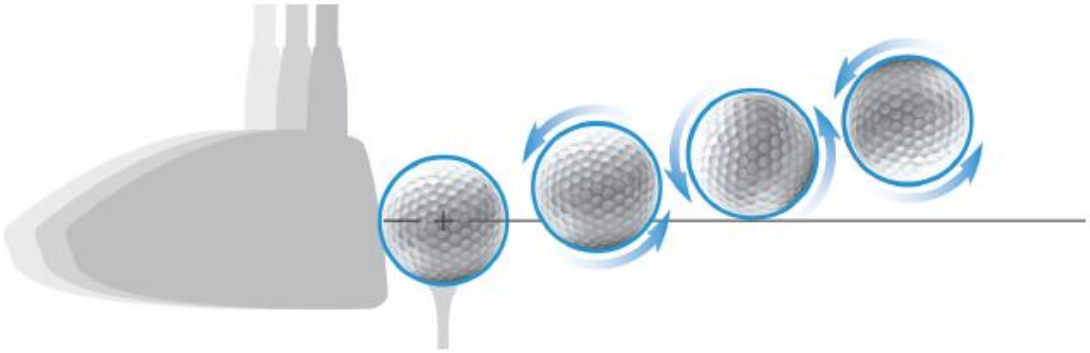
The horizontal launch direction is the angle between the ball and the target line on the horizontal plane at the moment of launch. It is also called the azimuth angle, and the unit is degrees.



If the ball fly in the same direction as the target, we call it a "straight shot". If the ball travels towards the side of the hitter, we generally call it a "pull" or "left pull". Conversely, it is called a "push" or "right push".

3.4 Spin

When a golf ball is hit, in addition to gaining launch speed, it also spins, measured in revolutions per second (rpm). The speed and direction of the spin are closely related to the angle of attack, dynamic clubface angle, and the angle of the clubface relative to the swing path. The spin speed is also closely related to the clubhead speed, the ball's stiffness, and the cleanliness of the clubface.



Spin has a significant impact on the lift and drag generated by a golf ball during flight, affecting its flight distance, altitude, trajectory curvature, and roll after landing.

Causes of spin:

(1) The dynamic loft angle and angle of attack of the clubface at impact will cause backspin on the ball. We call the dynamic clubface angle – angle of attack the backspin angle, as shown in the figure, the backspin angle is 14.8 - (-1.4) = 16.2°. This angle directly affects the magnitude of the backspin velocity. At the same clubhead speed, the larger this angle is, the greater the backspin component.

(2) Secondly, the opening and closing of the clubface relative to the swing path

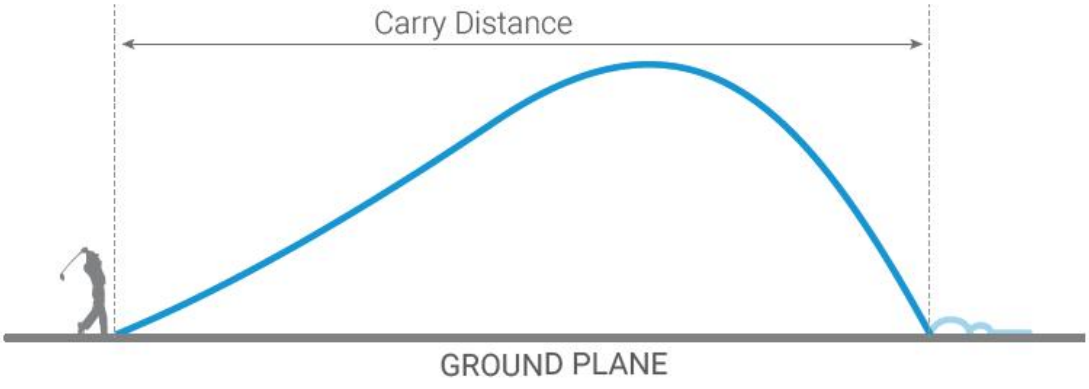
will cause the ball to generate sidespin. The angle of the clubface relative to the swing path is called the sidespin angle. At the same clubhead speed, the larger this angle is, the greater the sidespin component.

4. Ball Flight Trajectory

The flight trajectory is described by the flight distance, flight altitude, landing angle, and lateral deviation. The main factors affecting the flight trajectory are ball speed, takeoff angle, takeoff heading angle, total spin, and axis of rotation. In practice, environmental factors such as altitude, temperature, and wind must also be considered. In reality, your striking position and landing point are not necessarily on the same horizontal plane, which will also affect your actual flight distance.

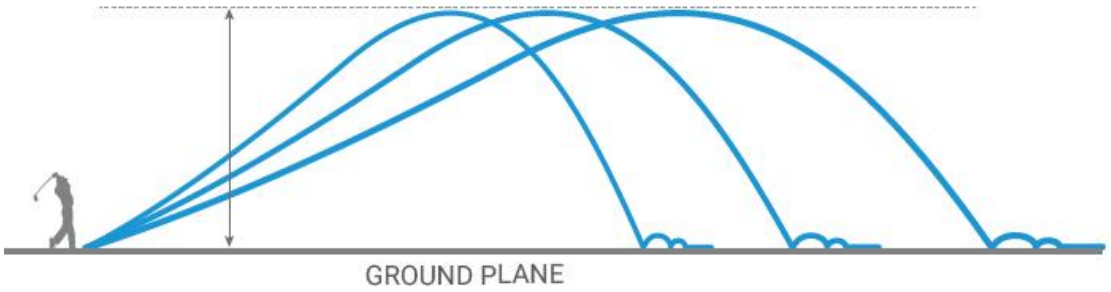
4.1 Flight Distance (Carry)

The distance the ball travels in the air. Carry assumes that the landing area and the striking point are on the same horizontal plane.



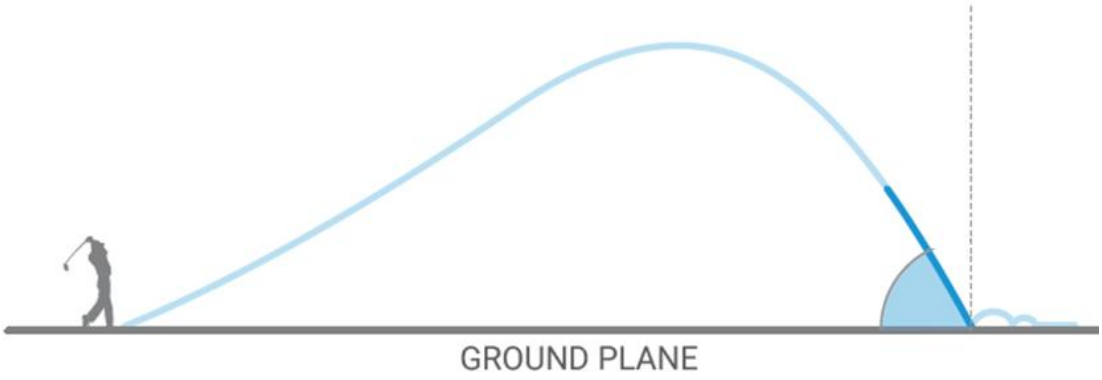
4.2 Flight Height

The highest altitude at which the ball flies.



4.3 Landing Angle

The angle at which the ball lands indicates how steep the landing is, and this data has a significant impact on the ball's roll.



4.4 Lateral Offset

The distance by which the ball's landing point deviates from the target line.