# The Ball: Aerodynamics
## Background Information



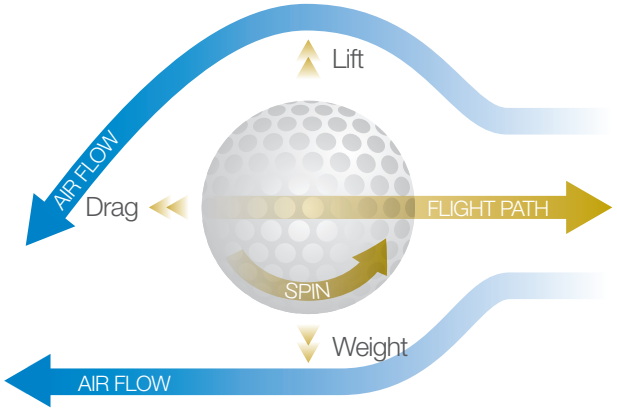
When you hit the perfect shot and send the ball soaring, what makes it fly so far? The power of your swing plays an important part, but so does the design of the ball itself. What may look like a simple ball is actually a marvel of science and engineering — and understanding how a golf ball moves through the air can help you design better ones to fly even higher and farther!

### Something in the Air

It all starts with the air around us. While we don't ordinarily feel the **weight** of air, it's actually full of gas molecules that exert **pressure** (or push) on everything they surround. This pressure acts evenly on all sides of an object, pushing down on the top as much as it pushes up on the bottom. So what makes a golf ball (or even an airplane) fly?

**Aerodynamics**, the science of how objects move through the air, has the answer. When you hit the ball, you provide the initial momentum to the ball. As it heads along its **flight path** toward the hole, the ball pushes through the air, creating wind resistance. This wind resistance pushes back against the ball, creating **drag,** a force that causes a moving object to slow down. You can feel drag in the wind against your face when you ride a bike downhill, or see its power if you try to hit a golf ball directly into the wind.

If the ball had no spin, then that would be the end of the story. However, golf balls usually have backspin. Because of this, the air moving over the top of the ball moves faster (relative to the ball) than the air moving under the ball. The faster the air moves, the less pressure it exerts, an effect that is called **Bernoulli's Principle.** This lower pressure air above the ball helps generate **lift**, a force that pushes the ball upward, helping it to travel farther. These forces (drag, lift) affect how high and far a golf ball can move.




Lift and Drag

### Building a Better Ball

The first golf balls were hard wooden balls, which didn't go very far. In the 17th century, a new type of ball was created by stuffing a wet leather pouch with goose feathers and sewing it up, which shrank into a hard, compact ball as it dried. These **featheries** could fly better than wooden balls, but were expensive to make and very fragile. Then in 1848, Robert Adams tried making golf balls out of gutta-percha (a rubbery sap from tropical sapodilla trees). More solid and resilient than featheries, these **gutties** could move faster and bounce better, and quickly became popular. About 50 years later, Coburn Haskell created the first multi-layered golf ball, which had a solid rubber core that was wrapped in rubber bands and then covered with a layer of gutta-percha.

Modern golf balls have as few as one or as many as six different layers of solid material, usually polymers such as polybutadiene (a highly resilient synthetic rubber that is also used in car tires). For example, a professional golf ball might have a thin rubber cover, an inner layer of stiff plastic, and a solid core of polybutadiene.

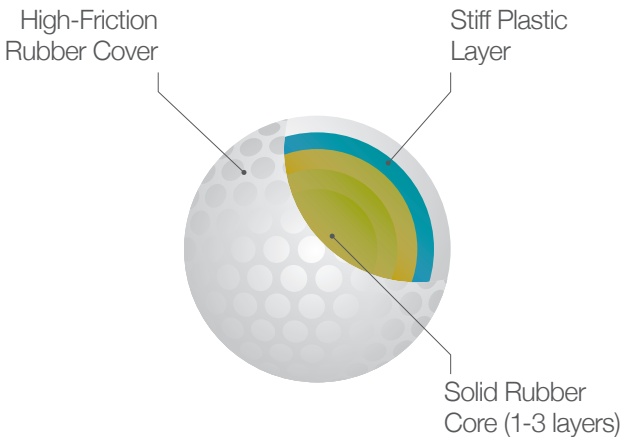
### What's with the Dimples?

Something else that most golf balls have in common is dimples — the little dents all over the ball. Dimples may seem to be there just for decoration, but they actually have a specific aerodynamic purpose. Back in the 19th century, players discovered that dented old gutties flew farther than smooth new ones, so they began

hammering dents into them deliberately. At the time, they may not have known exactly why the dents helped. But we now know it's because these imperfections create **turbulence** in the **airflow** around a moving ball, which makes its wake (the air behind the ball) thinner and reduces drag.

Dimples also increase **spin.** As a ball moves forward through the air, the dimples cause the ball to actually spin backwards, pulling the airflow downwards. As this happens, the air at the bottom of the ball pushes up against the ball (**Newton's Third Law**), creating more lift. So dimples are a small design feature with a big impact.

## Good Design, But Not Too Good




Anatomy of a Sample Golf Ball

Today's golf balls fly farther and are engineered better than at any time in history. But balls shouldn't be so good that a player's skill no longer matters, which is why the USGA has created specific standards — a golf ball can't be smaller than 1.68 inches in diameter (but no maximum size), can't be heavier than 1.62 ounces (but no minimum weight), can't go faster than 255 feet/second when hit by the USGA's impact machine, can't go any farther than 317 yards when hit at 120 mph, must be spherically symmetric, and must not contain unusual construction features.

It's not difficult to check the weight, size, or shape of a golf ball, but how do you figure out whether it conforms to those limits on distance and speed? With a robot golfer, of course! The robot golfer hits the ball off a tee with a 120 mph swing speed to see how fast the ball leaves the tee, and to find its initial angle and spin. The USGA Equipment Standards Department then uses a high-speed launcher to shoot the ball at speeds up to 200 mph through a 70-foot tunnel of sensors, which helps the USGA learn about its aerodynamic performance. Combining the launch data from the robot golfer with the aerodynamic data from the tunnel, the USGA can accurately simulate golf ball trajectories.

The USGA tests more than 30,000 golf balls per year to make sure that they are within the rules. This system is also used by golf ball companies around the world to test new ball designs (and not just for the fun of using a robot).

**▲ Test Center**

The golf ball tunnel at the USGA Test Center (Copyright USGA/John Mummert)

This information is adapted from NBC Learn: Science of Golf, "Evolution of the Golf Ball" (www.nbclearn.com/science-of-golf) and "STEMZone and the World of Golf" (www.kidscoopnews.com/stem-zone/)

# Key Concepts



### Aerodynamics
The science of how objects move through the air. The word comes form the combination of the Greek words *aeroes* (of the air) and *dynamis* (power, strength, force).

### Airflow
The motion of air. In the case of a golf ball, airflow refers to how air moves around and/or past a ball as it travels.

### Air Pressure
A force caused by air pressing (or pushing) on an object. Air continually exerts pressure on everything it surrounds.

### Bernoulli's Principle
A scientific principle that states that moving air causes less pressure on an object than still air. This is also true of moving fluids (like water).

### Dimples
Dents on a golf ball that help it travel farther through the air. They do this by creating turbulence in the airflow around the ball, which reduces drag.

### Drag (Air Resistance)
A force created by air pushing back against a moving object, which causes it to slow down. Most round objects (like a golf ball) have less drag than flat objects (like a cube).

### Flight Path
The direction in which a golf ball travels through the air.

### Force
The means by which an object is pushed or pulled.

### Golf Ball (Featherie)
In the 17th century, golf balls were created by stuffing a wet leather pouch with goose feathers and sewing it up, which then shrank into a hard, compact ball as it dried. Featheries could fly better than earlier wood balls, but were expensive to make and very fragile.

### Golf Ball (Guttie)
In the mid-19th century, golf balls were made out of gutta-percha (a rubbery sap from tropical sapodilla trees). Gutties were more solid and resilient than featheries, so they could bounce better and fly faster, but also stop quickly when landing.

## Golf Ball (Modern)

Golf balls today have as few as one or as many as six different layers of solid material, usually polymers such as polybutadiene (a highly resilient synthetic rubber that is also used in car tires).

## Gravity

A force of attraction that pulls objects toward each other. The more mass an object has, the stronger its gravitational pull.

## Lift

A force that lifts an object upward due to the difference between the air pressure above and below it. The air moving over the top of a golf ball travels faster than the air below it, causing the ball to move upward.

## Mass

The amount of matter in an object. The more mass an object has, the more force is required to move it.

## Newton's Laws of Motion

Scientific principles established by English scientist Isaac Newton in the 17th century. *First law:* an object at rest will stay at rest, or an object in motion will stay in motion at a constant speed, unless an external force acts on it. *Second law:* when a force acts on an object, the object will move in the same direction that the force was moving. *Third law:* any object will react to a force applied to it, and the force of the reaction will be equal to and in the opposite direction of the original force applied.

## Speed

The measure of how fast an object travels a specific distance over a specific time.

## Spin

The circular motion of a golf ball as it travels through the air. As a ball moves forward through the air, the dimples cause the ball to actually spin backwards, pulling the airflow downwards. As this happens, the air at the bottom of the ball pushes up against the ball, creating more lift.

## Turbulence

Irregular or agitated motion of the air. You can feel this when an airplane encounters turbulence and starts to shake.

## Velocity

The measure of speed in a specific direction.

## Weight

The measure of the pull of gravity on the mass of an object. The weight of an object makes it harder to lift or stay aloft in the air.