**Case Study**

**Manufacturing**

**Source:** <http://www.madehow.com/Volume-3/Golf-Ball.html#ixzz56rhJEgE9>

Golf, a game of Scottish origin, is one of the most popular sports in the world. In the United States alone more than 24 million people play golf, including over 8,000 professional players. Golf tournaments around the world are popular with spectators, as well as with players, and since the 1960s, they have received wide television coverage. There is now even a cable channel devoted to golf, as well as numerous computer games.

The basic game involves using a variety of clubs to drive a small ball into a succession of either nine or 18 holes, over a course designed to present obstacles, in as few strokes as possible. A player is permitted to carry a selection of up to 14 clubs of varying shapes, sizes, and lengths. The standard golf ball used in the United States is a minimum of 1.68 in (4.26 cm) in diameter; the British ball is slightly smaller.

A golf course generally has 18 holes spread over a landscaped area that includes a number of hazards, including water, sand traps or bunkers, and trees. Difficulty is increased by varying distances among holes. Play on each hole is begun at the tee area, from which players drive the ball into the fairway. Each hole can vary in length from about 150-600 yards (135-540 m); successful players are those who are able to drive the ball more than 200 yards (180 m) from the tee, approaching most holes with fewer than three shots. At the end of the hole is the putting green, where the ball must be putted into the hole or cup to complete the hole.

Golf is usually played by groups of two to four people who move throughout the course together. The ball must be played from where it lies, except in specific circumstances. In stroke competition, the total number of strokes used to move the ball from the tee to the hole is recorded as the players' score for that individual hole. The player who uses the fewest strokes to complete the course is the winner. In match play, scores are compared after every hole, and a player wins, loses, or halves (ties) each hole.

Each hole must be reached in a specific number of shots (par), which usually depends on length. A birdie is a score on any one hole that is one stroke less than par, and an eagle is a score on a hole that is two less than par. A hole in one is scored when the player drives the ball into the hole with only one stroke.

**Golf Balls**

Today, the golf ball market is worth around $550 million in annual sales, with over 850 million golf balls being manufactured and shipped every year. Currently, balls are made in two or three parts. A two-piece ball is made of rubber and plastic, and is mostly used by the casual golfer. These balls last a lot longer than the three-piece balls the pros use and hence make up 70% of all golf ball production. A three-piece ball consists of a plastic cover, windings of rubber thread, and a core that contains a gel or liquid (sugar and water) or is solid. A dimple pattern on the surface results in good flight performance.

The most common dimple patterns are the [icosahedral](http://www.madehow.com/knowledge/Icosahedron.html), the dodecahedral, and the octahedral. The icosahedral pattern is based on a polyhedral with 20 identical triangular faces, much like a 20-sided die. Similarly, a dodecahedral is based on a polyhedral with 12 identical faces in the shape of pentagons. The octahedral is based on an eight-sided polyhedral with triangular faces. Some balls are based on the icosahedral with 500 dimples. As a general rule, the more dimples a ball has the better it flies, provided those dimples are about 0.15 in (0.38 cm) in diameter.

The size and depth of the dimples also affect performance. Shallow dimples generate more spin on a golf ball than deep dimples, which increases lift and causes the ball to rise and stay in the air longer and roll less. Deep dimples generate less spin on a golf ball than shallow dimples, which decrease lift and causes the ball to stay on a low trajectory, with less air time and greater roll. Small dimples generally give the ball a lower trajectory and good control in the wind, where as large dimples give the ball a higher trajectory and longer flight time.

Technological advances in materials and aerodynamics now allow the manufacturer to custom-fit a golf ball for a players' particular game, for weather conditions, and even for specific course conditions. Golf balls can be separated into four basic performance categories: distance and durability; control and maneuverability; distance and control; and slow clubhead speed. Within these categories there are more than 80 different balls of varying construction materials and design.

The [United States Golf Association](http://www.madehow.com/knowledge/United_States_Golf_Association.html) (USGA) has established rules for the ball in regard to maximum weight, minimum size, spherical symmetry, initial velocity, and overall distance. The weight of the ball must not be greater than 1.62 oz (45.93 g) and must be spherically symmetrical. The velocity shall not be greater than 250 feet (75 m) per second (255 feet [76.5 m] per second maximum) when measured on apparatus approved by the USGA. The overall distance standard states that the ball shall not cover an average distance in carry and roll exceeding 280 yards (84 m) (296.8 yards [89 m] maximum). These rules are updated every year.

Currently, there are around 850 models of balls that conform to these standards. Recently, balls that are about *2%*larger than ordinary balls have been introduced that still conform to USGA rules. These balls have softer cores and thicker, harder covers, which leads to a straighter, longer shot.

**Case Problem**

Sporting goods manufacturing company wanted to compare the distance traveled by golf balls produced using four different designs. Ten balls were manufactured with each design and were brought to the local golf course for the club professional to test. The order in which the balls were hit with the same club from the first tee was randomized so that the pro did not know which type of ball was being hit. All 40 balls were hit in a short period of time, during which the environmental conditions were essentially the same. The results (distance traveled in yards) for the four Designs are stored in Golfball.

1. At the 0.05 level of significance, is there evidence of a difference in the mean distances traveled by the Design 1 and Design 2 golf balls?
2. At the 0.05 level of significance, is there evidence of a difference in the mean distances traveled by the golf balls with different designs?

**Data file: Golfball.csv**