Student Explorations in Mathematics

It's a Hit!
The Mathematics in Baseball

"It ain't over 'til it's over." Yogi Berra

"Baseball is the only field of endeavor where a man can succeed three times out of ten and be considered a good performer." Ted Williams

Baseball is a game of senses: The crack of the bat, the roar of the crowd, rubbing the dirt on your hands, the intensity in the pitcher's eyes . . .

You can also use your mathematical sense in the game. You can calculate the stolen base percentage against a given catcher or the on-base percentage plus slugging percentage for any given player. These statistics are easy to find because Major League Baseball officially publishes 28 different batting statistics, 42 different pitching statistics, and 15 different fielding statistics.

In this activity, you will be looking into statistics that might not be available on mlb.com or other baseball sites.

1. Aside from the players and the plays, identify other information you want to know about the game of baseball.

Work your way through this series of questions and see how math is used to calculate a wide variety of baseball statistics.

Some people date baseball to the 1700s, but it became popular when its rules were codified soon after the Civil War. During the many years that the game has been played, the ball itself has undergone numerous changes. Materials used to construct both the inside and outside of a baseball have been tested, alternately resulting in advantages to pitchers and to batters. In this activity, we will explore some facts about the modern baseball.

Have you ever seen a fan actually return a foul ball hit to the field during a game? Most likely the answer is no. Aside from foul balls and home runs, Major League Baseball (MLB) teams lose or replace a large number of

baseballs during every game. The cost of each ball and the number of times an individual ball is pitched must be taken into account when planning for a new season.

2. If the average number of baseballs used during a nine-inning MLB game is 108, and each of the 30 MLB teams plays 162 games per season—

a. how many baseballs are used per season in MLB?

3. According to a Seattle Mariners representative, as of July 2013, MLB teams pay $93 per dozen baseballs.

a. What is the average cost of each baseball used in MLB?

b. What is the average cost of baseballs per season in MLB?

c. What is the average cost of baseballs per team?

d. If each MLB team plays 81 home games per season, what is the average cost of baseballs per game?

4. If the average number of pitches thrown by each team in a nine-inning MLB game is 146, what is the average cost per pitch of baseballs in MLB?

5. Using the diagram of an MLB field, determine the following measurements:

a. What shapes do you see?

b. What is the distance between each base?
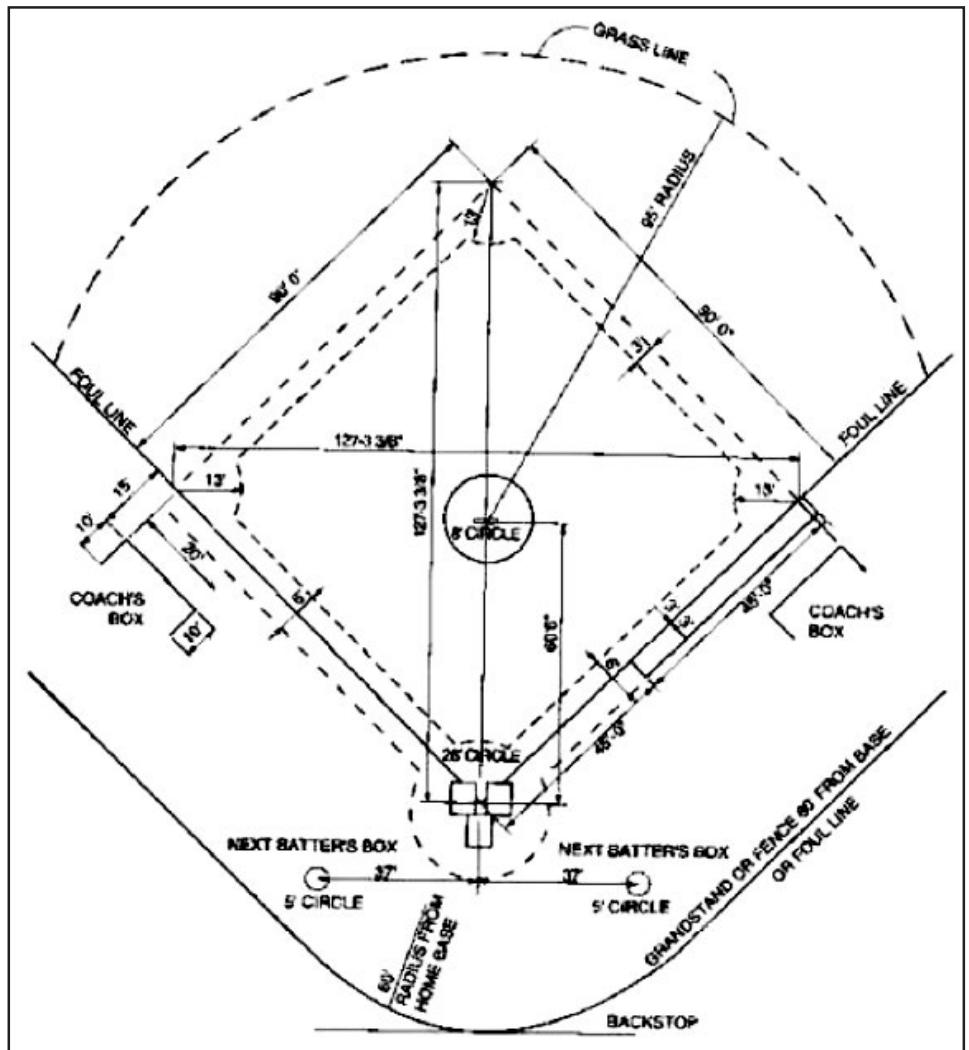
c. What is the distance from the pitcher's mound to home plate?

7. A typical MLB pitcher throws a fastball that travels 90 miles per hour.

   a. How many feet per second does the ball travel?

6. Use the information from question 5 to find the following, rounding answers to the nearest hundredth of a foot:

   a. The distance from home plate to second base

   b. At this speed, how long does it take for the baseball to reach home plate? In other words, what is the reaction time for the batter?

   b. The distance from the pitcher's mound to first base

8. A pitcher throws a baseball at a speed of 100 miles per hour.

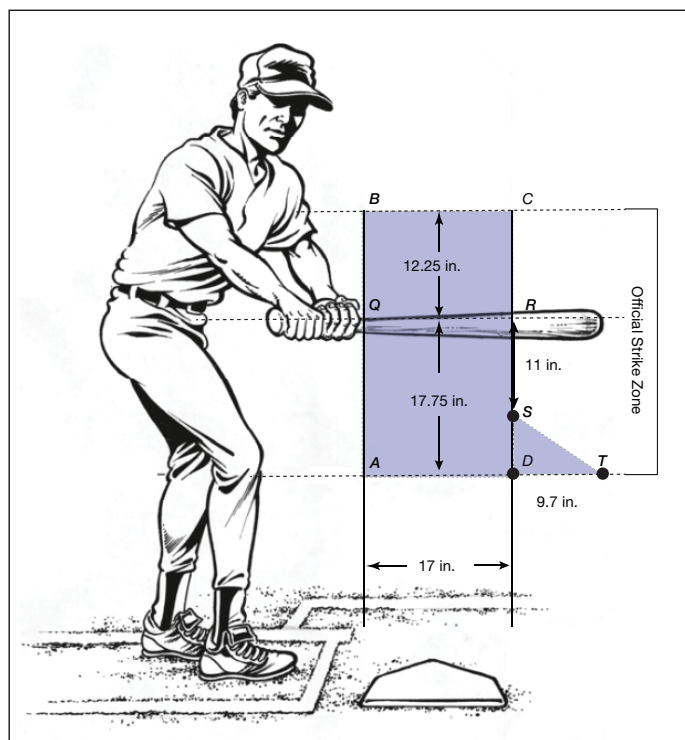   a. How many feet per second does the ball travel?

Assume that the pitcher throws to each base at the rate of 100 mph. Using your answer from question 7a, how long does it take for the baseball to travel from the pitcher's mound to—

   b. home plate?

   c. first base?

   d. second base?

9. Use the Fastball Reaction Time app to determine if you can hit a fastball at this velocity.

   a. Swing the bat ten times. Track your reaction time and result (i.e., swing and a miss; base hit) for each swing.

   b. Analyze the results, then write a short paragraph about your findings.

In MLB, the strike zone "is a conceptual right pentagonal prism over home plate which defines the boundaries through which a pitch must pass to count as a strike when the batter does not swing" (en.wikipedia.org/wiki /Strike_zone).

Official major league rules define the strike zone (refer to *ABCD* in the following diagram) as "that area over home plate the upper limit of which is a horizontal line at the midpoint between the top of the shoulders and the top of the uniform pants, and the lower level is a line at the hollow beneath the kneecap. The strike zone shall be determined from the batter's stance as the batter is prepared to swing at a pitched ball." The right and left boundaries correspond to the edges of home plate. Before 2001, however, the strike zone was changed to a smaller region (refer to *AQRST* in the following diagram). In 2001, MLB mandated that umpires return to enforcing the original strike zone.

10. Using the diagram of the two different strike zones for an average-size player—

   a. find the area of the original strike zone, *ABCD*.

   b. find the area of the pre-2001 strike zone, *AQRST*.

   c. determine how much larger the original strike zone is compared with the pre-2001 strike zone.

   d. by what percentage had the area of the strike zone *ABCD* decreased when it changed to *AQRST* in.^{2}?

Collins English Dictionary defines a home run as "a hit that enables the batter to run round all four bases, usually by hitting the ball out of the playing area" (over the outfield fence).

11. A baseball that is headed toward the center field fence follows a path modeled by the equation $y = -0.002x^2 + 0.6837x - 5$, where x represents the ball's horizontal distance, in feet, from home plate, and y represents the ball's height, in feet, above the ground. In which MLB parks would this be a home run? Assume that the fence in center field is 8 feet high.

The game of baseball uses a large number of statistics. *Sabermetrics*, which is derived from the acronym *SABR*, which stands for Society for American Baseball Research, was a term coined by baseball author and researcher Bill James. He and others created new statistics other than only batting average with which to measure an offensive player's productivity, as well as predict future productivity.

Three widely used statistics from sabermetrics, and how to compute them, follow:

- batting average (BA). For batters, this is the most referred-to stat. Batting average is the ratio of hits (H) to at bats (AB). The formula is BA = H/AB.

- slugging percentage (SLG): This statistic takes into account the difference between singles and home runs. Slugging percentage is equal to total bases divided by at bats. The formula is SLG = TB/AB.

  Note: Total bases (TB) = 1(1B) + 2(2B) + 3(3B) + 4(HR)

- On-base percentage (OBP): This statistic indicates how often a player reaches base due to a hit, a walk, or being hit by a pitch. On-base percentage is equal to hits (H) + bases on balls (BB) + hit by pitch (HBP) divided by plate appearances (PA). The formula is OBP = (H + BB + HBP)/PA.

12. Complete the table below using these player statistics:

- Carl Yastrzemski (Red Sox, 1967): PA (680); AB (579); H (189); 2B (31); 3B (4); HR (44); BB (91); HBP (4)

- Adam Dunn (Reds, 2002): PA (676); AB (535); H (133); 2B (28); 3B (2); HR (26); BB (128); HBP (9)

- Lance Berkman (Astros, 2003): PA (658); AB (538); H (155); 2B (35); 3B (6); HR (25); BB (107); HBP (9)

- Adrian Gonzalez (Padres, 2009): PA (681); AB (552); H (153); 2B (27); 3B (2); HR (40); BB (119); HBP (5)

- Miguel Cabrera (Tigers, 2012): PA (697); AB (622); H (205); 2B (40); 3B (0); HR (44); BB 66); HBP (3)

- Mike Trout (Angels, 2012): PA (639); AB (559); H (182); 2B (27); 3B (8); HR (30); BB (67); HBP (6)

Player's Name	Team	Year	PA	AB	Hits	1B	2B	3B	HR	BB	HBP	BA	OBP	SLG
Carl Yastrzemski	Red Sox	1967												
Adam Dunn	Reds	2002												
Lance Berkman	Astros	2003												
Adrian Gonzalez	Padres	2009												
Miguel Cabrera	Tigers	2012												
Mike Trout	Angels	2012												

Can you …

- calculate how much faster, in terms of distance, a four-seam fastball gets to home plate than a two-seam fastball?

- calculate the surface area of a regulation baseball?

- collect and compare data about MLB parks and Japanese baseball parks?

Did you know that …

- Dodgers General Manager Branch Rickey hired the first baseball statistician in 1947?

- a headfirst slide is better than feet first? According to David Peters, a physicist at Washington University in St. Louis, arms are lighter than legs, which means as the body rotates, arms extend out a bit farther than legs. Feet also give an extra push.

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