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Put a Spin On It – The Effect of Spin on Balls in Motion

Background, Purpose, and Hypothesis

In sports such as tennis, baseball, golf, and ping-pong, one notices that the path of a ball curves if it is given spin when thrown or hit. This curved path, common in sports, is because of the Magnus force. The Magnus force is caused by a pressure differential between opposite sides of the ball as it moves through the air. This pressure differential is caused by the surface texture of the ball, which will carry some air with it as the ball spins. Air is carried forward by the part of the ball that is spinning in the same direction the ball is moving. This increases the concentration of air on that side of the ball, and therefore increases the air pressure. On the opposite side, air carried away by the ball reduces the concentration of air, and therefore decreases the air pressure. If a ball has a greater pressure above it than below it, the Magnus force and deflection will be downwards. If a ball has a greater pressure below it than above it, the Magnus force and deflection will be upwards.

This experiment will investigate the effect of spin on balls in motion, by measuring the pressure differential between opposite sides of a ball experiencing wind and spinning at various speeds. Four balls, a tennis ball, a baseball, a golf ball, and a ping-pong ball, will be studied.

From experience and from watching sports, we know that the more spin one puts on a ball, the greater its deflection will be. Thus, the greater the spin of a ball, the greater its pressure differential will be. Since a spinning ball does nothing unless it is moving through the air, the greater the air velocity against a ball, the greater its pressure differential will be. In comparing the surface textures of the four different balls, the fuzz of the tennis ball will carry the most air with it followed by the laces of the baseball, and the dimples of the golf ball. The smooth surface of the ping-pong ball will carry the least amount of air with it. This means that the rougher the surface texture, the greater the pressure differential will be.

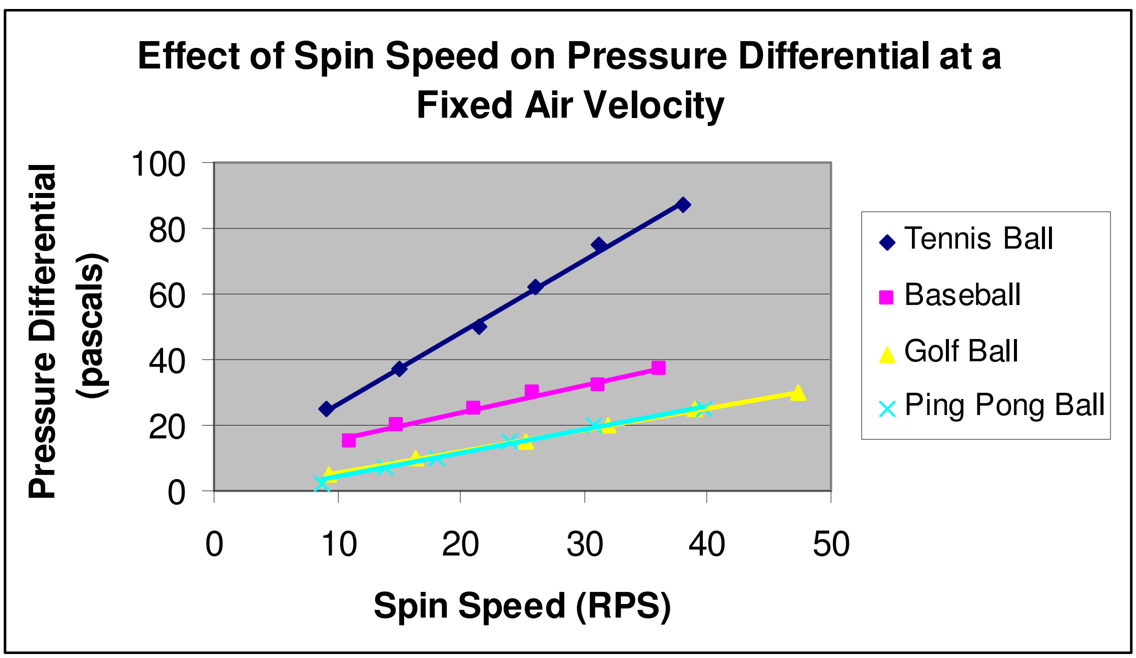
Procedure

The four different balls were drilled directly through the centre. A wooden rod was inserted through each ball. The rod was attached to a motor and set in a stabilizer ring. The ends of monometer #1 were positioned on opposite sides of the ball, as close to it as possible to measure the pressure differential. A pitot tube, connected to manometer #2, was positioned near the front of the ball to measure velocity pressure. A blower was lined up with the ball. The blower was turned on and a velocity pressure reading was taken from manometer #2 to calculate air speed. The spin motor was turned on and the rate of spin controlled with a rheostat until manometer #1 showed that the ball was producing a steady pressure differential. The rate of spin in revolutions per second (RPS) of the motor was calculated using a spin counter and stopwatch. The motor rate of spin was varied with the rheostat until another steady pressure differential was produced, and the RPS was calculated. This process was repeated until 6 distinct pressure differentials were produced and their corresponding rates of spin were calculated. The ball was then set spinning at a constant rate and the RPS was calculated. The blower was turned on at one rate. A velocity pressure reading from manometer #2 was used to calculate air speed. A pressure differential reading was taken from manometer #1. The air speed was varied by switching the blower's speed settings and moving the blower further away until a new pressure differential was produced, and the air speed was then calculated. This process was repeated until 6 distinct pressure differentials were produced and their corresponding air speeds were calculated. The procedure was repeated for each of the four balls.

Results and Conclusions

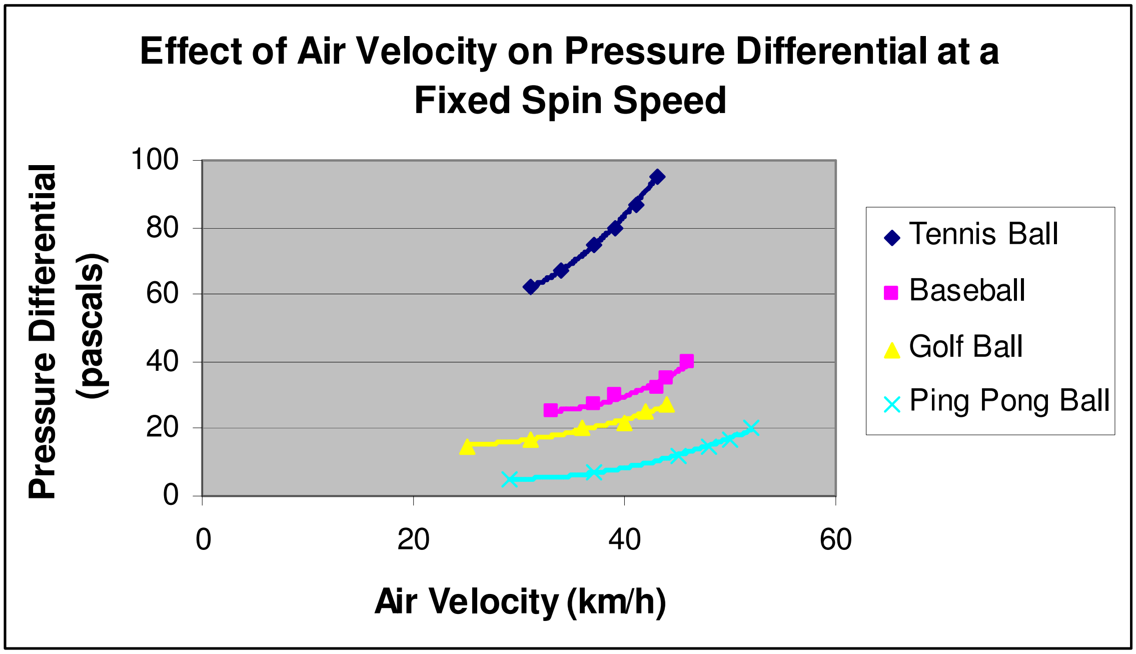
For all balls, as the spin speed of the ball increased, the pressure differential also increased. The relationship between pressure differential and spin speed is linear, so pressure differential is proportional to the spin speed. (See Graph 1)

Graph 1



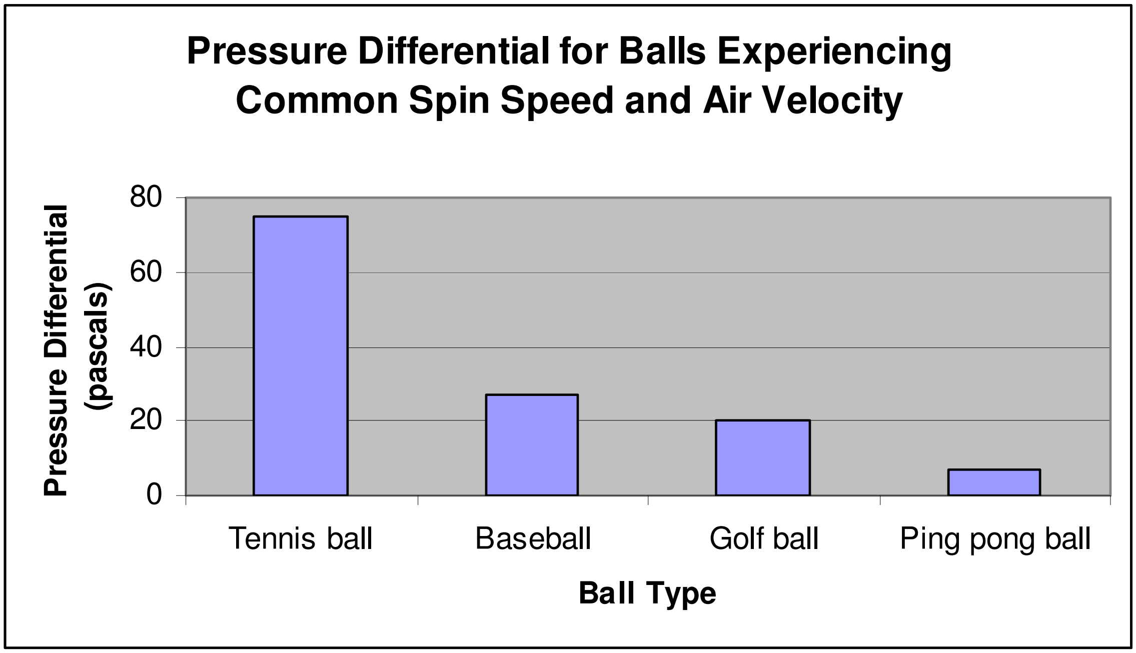
For all balls, as the air velocity against the ball increased, the pressure differential also increased. The relationship between pressure differential and air velocity is quadratic, so pressure differential is proportional to the square of the air velocity. (See Graph 2)

Graph 2



As predicted in my hypothesis, the surface texture of each ball did influence the pressure differential generated. Overall, the tennis ball produced the largest pressure differential. The tennis ball was followed by, in decreasing order, the baseball, golf ball, and ping-pong ball. The fuzz of the tennis ball carried the most air with it. The laces of the baseball carried the next most, followed by the dimples of the golf ball. The smooth surface of a ping-pong ball carried the least amount of air with it. From these results, we can see that the more textured a ball, the greater the pressure differential will be. Thus, pressure differential is proportional to the surface roughness of the ball. (See Graph 3)

Graph 3



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Appendix

Bibliography

Achutarao, Krishna. "The Magnus Effect." 30 January 2006 <http://www.geocities.com/k_achutarao/MAGNUS/magnus.html>.

"Airflow."Air Systems. Publication 200. Air Movement and Control Association, Inc., 1987.

Briggs , Lyman. "Effect of Spin and Speed on the Lateral Deflection (Curve) of a Baseball; and the Magnus Effect for Smooth Spheres." 26 March 1959. The American Journal of Physics. 3 March 2006 <http://scitation.aip.org/getabs/servlet/GetabsServlet?prog=normal&id=AJPIAS0000270000008000589000001&idtype=cvips&gifs=yes>.

Carini, John. "Effects of Spin." Physics of Sports. 26 July 2005. Indiana University. 30 January 2006 <http://carini.physics.indiana.edu/e105/spinning-balls.html>.

"Curveball Aerodynamics." Beginner's Guide to Aeronautics. NASA. 5 March 2006 <http://www.grc.nasa.gov/WWW/K-12/airplane/bball.html>.

Gardner, Robert. Science and Sports. New York: Franklin Watts Inc., 1988.
"Build Your Own Manometer." The Science House. NC State University. 24 January 2006 <http://www.science-house.org/student/bw/flight/manometer.html>.

"Measurement of Pressure with The Manometer." Dwyer Instruments. Dwyer. 21 January 2006 <http://www.dwyer-inst.com/htdocs/pressure/manometerintroduction2.cfm>.

Nave, R. "Curve of a Baseball." Pressure. HyperPhysics. 14 January 2006 <http://hyperphysics.phy-astr.gsu.edu/Hbase/pber.html>.

Phillips, Tony. "Moon Tennis." 30 August 2005. NASA. 6 February 2006 <http://science.nasa.gov/headlines/y2005/30aug_moontennis.htm>.

"Pitot Traverse in Outlet Duct."Laboratory Methods of Testing Fans for Rating. Standard 51-75. American Society of Heating, Refrigerating and Air Conditioning Engineers, 1975.

"Pressure Calculation for Manometers." eFunda: The Ultimate Online Reference for Engineers. eFunda. 16 January 2006 <http://www.efunda.com/formulae/fluids/manometer.cfm>.

"Specifications - Instructions and Operation."Mark II Series Molded Plastic Manometers. Bulletin D-58. Dwyer Instruments, Inc., 2004.

"Why does a golf ball have dimples?." Aerodynamics in Sports Equipment, Recreation and Machines. 7 May 1998. Cislunar Aerospace, Inc.. 5 March 2006 <http://wings.avkids.com/Book/Sports/instructor/golf-01.html>.