SALISBURY UNIVERSITY DEPARTMENT OF PHYSICS

BOWLING BALL CORE SHAPE DYNAMICS

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MOMENT OF INERTIA DYNAMICS OF SHAPED BOWLING BALL CORES

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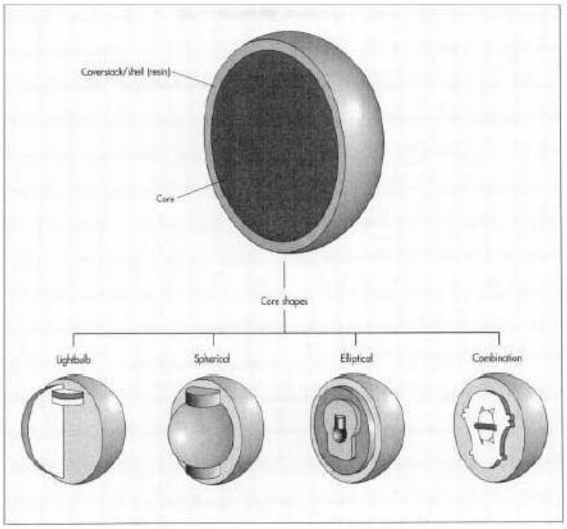
ABSTRACT

A bowling ball's dynamical path can be influenced by the density of material, shape, size, axis of rotation, and positioning of the designed core within a bowling ball. Through theoretical and experimental calculations, along with experimental data gathered through use of bowling ball cores, it is hoped that predictions can be made as to what particular paths different bowling balls will follow and to their respective pin carry effectiveness.

INTRODUCTION

The history of Bowling is thought to have ancient origins after Sir Flinders Petrie, discovered in the 1930's a collection of objects in a child's grave in Egypt that appeared to him to be used for a crude form of bowling. If he was correct, then bowling traces its ancestry to 3200 BC.[1] Others believe that bowling started anywhere from 300 AD in Germany to 1366 in England when King Edward III allegedly outlawed it to keep his troops focused on archery practice.[1] The game of bowling has seen several different variations as it has progressed through time with one being where a player heaves a ball through their legs towards the pins. The sport gained popularity in America during the 1800's using a ball rolled toward an arrangement of nine pins. Because of rumored gambling concerns local Connecticut authorities in 1841 passed a law to ban ninepin bowling lanes, and people were said to circumvent this by adding an extra pin, starting ten pin bowling.[2] Across the United States,

though the game was common, the pin and ball sizes varied from region to region until a restauranteur by the name Joe Thum finally pulled together representatives of the various regional bowling clubs, creating the American Bowling Congress in 1895.[1] In the early 1900s, standardized bowling ball designs and specifications began to appear as the sport began to become more regulated.



The basic bowling ball must have a circumference of at least 26.704 inches and no more than 27.002 inches.[3] The weight of the ball can be no more than 16 pounds but has no minimum weight. The diameter of the ball must be constant throughout the entire ball and the ball must have no grooves or indentations of specific patterns save for those designed for gripping the ball, identification letters and numbers, and chipping caused by wear. On the grounds of drilling holes into the ball, you are only allowed up to five holes for gripping which can not exceed 1¼ inches in diameter, one vent hole for each finger and/or thumb hole, and one mill hole for purposes of inspection which can not exceed 5/8th inches in diameter and 1/8th inches in depth.[4] The ball itself must be made of some non-metallic material.[4] Inside each bowling ball there is a core whose shape, density, size, and placement can all affect the bowling ball's dynamics and pin carry effectiveness. Other physical parameters of core design governing a ball's dynamics can include: Radius of Gyration (distance between the axis of a rotating body and its center of gyration), Differential Radius of Gyration (difference in radius of gyration between any two spin axes of an object), and moment of inertia (a measure of the difficulty in rotationally accelerating a body).

The purpose of this research is too accurately predict how a bowling ball should react based solely upon experimental data and theoretical motional dynamics calculations of core shape, size, density and positioning within the bowling ball. Moment of inertia considerations will be crucial in these calculations and models. Some of the different core shapes that we will model will include spherical, cylindrical, and right triangular cones (Lane #1 Diamond Core), all of which could possibly be off the center of rotation and of different materials and densities.

METHODS

Moment of inertia quantifies the rotational inertia of an object, i.e. its inertia with respect to rotational motion, in a manner somewhat analogous to how mass quantify the inertia of an object with respect to translational straight line motion. The moment of inertia depends on the shape of the object, how the mass is distributed and where the axis of rotation is specified. In order to explore the moment of inertia for the different core shapes and densities, equations are needed to be derived using a formula similar to equation (1), where "r" is the radius and "m" is the mass.[5]

$$I = \int dI = \int_0^M r^2 dm \qquad (1)$$

Some already calculated results using equation (1) for moments of inertia ***(I)*** for some simple shapes are included in Figure 1.

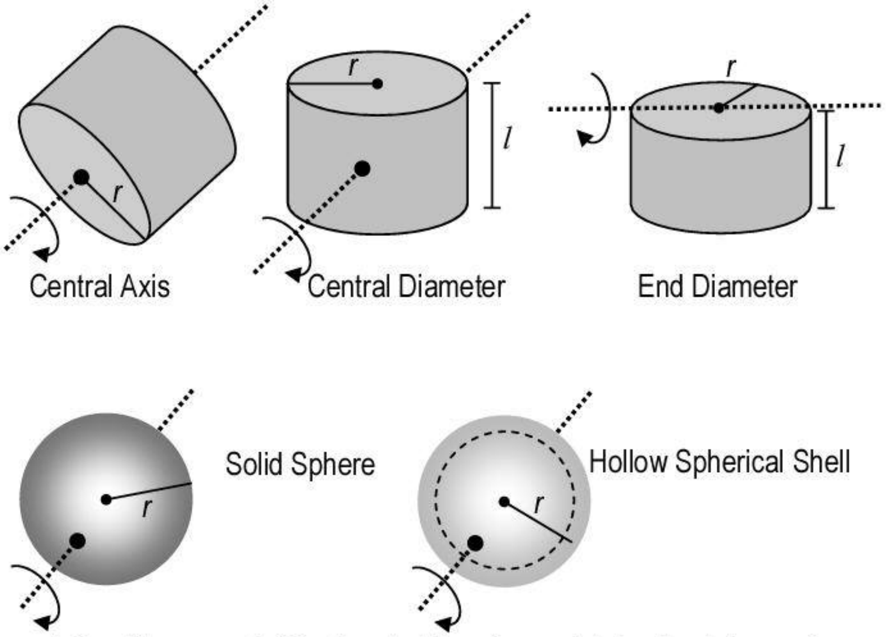


Figure 1: Resulting moment of inertia calculations for possible bowling ball core shapes. These results assume a uniform core density throughout the volume of the shape where *"m"* is the objects mass, *"r"* is the radius, and *"l"* is the length indicated.

By looking at the preliminary results in figure 1, for example, it can already be seen that a solid sphere core with a uniform density of known mass and size will have only 60% of the rotational inertia that a hollow spherical shell core will have of the same mass and size. It might be surmised from this result that if a ball manufacturer wants to have a ball that can be "rev'd up" (a ball that can more easily experience more revolutions as it travels down the lane) they should consider concentrating more mass towards the axis of rotation or gradually increase the density of the core material towards the rotational axis – but this must be tested.

The influence on ball dynamics of differing amounts of rotational inertia can be explored by completing more calculations of various core shapes and describing those influences. Some examples of bowling ball core shapes to be modeled are shown in figure 2.

Figure 2: Example core shapes that will be modeled by calculating rotational moments of inertia. [8,9]

The mathematical tools that are going to be used for the theoretical calculations of core moments of inertia as well as other components (e.g., radius of gyration) will be Mathematica, the DirectMath front end interface, and Maple.

To experimentally determine the moment of inertia for certain bowling balls, we will set up an experimental apparatus as seen in Figure 3. We can determine, using conservation of energy techniques (Equation 2), a derived formula using DirectMath and its Mathematica kernel can be derived (Equation 3) to experimentally calculate the rotational moment of inertia of the core (I_o).

$$mgh = \frac{1}{2}m\left(\frac{2h}{t}\right)^2 + \frac{1}{2}I_o\left(\frac{v_f}{r_p}\right)^2 \qquad (2)$$

$$I_o = \frac{\left(\left(gt^2 - 2h\right)m r_p{}^2\right)}{2h} \qquad (3)$$

The core will be secured to a rotational dynamics platform which will be attached to a gravitational hanging mass via a tension cord. The falling mass will cause the core to spin around a fixed axis of choice from which we will be able to experimentally calculate the moment of inertia of ball's core and compare to theoretical values (Figure 3). Example ball cores that will be extracted and tested on the rotational dynamics platform are shown in figure 4.

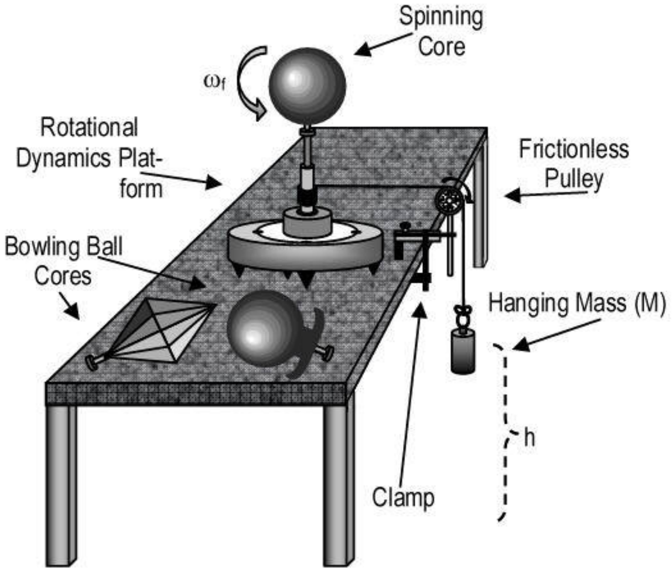


Figure 3: **The Rotational Dynamics Platform**: The bowling ball core will be spun around an axis by using gravitational potential energy of a falling hanging mass and string wound around the rotational axis and over a frictionless pulley. Using conservation of energy techniques the rotational moment of inertia of the core can be calculated experimentally.

After compiling the necessary theoretical calculations and experimental results, observational data must then be acquired through testing of bowling balls at a nearby bowling alley. Based upon the statistics released by various bowling ball manufacturers, a general idea of the path which the bowling ball will travel can be gathered due to the ball's radius of gyration which is a related property to moment of inertia (Table 1 & 2).

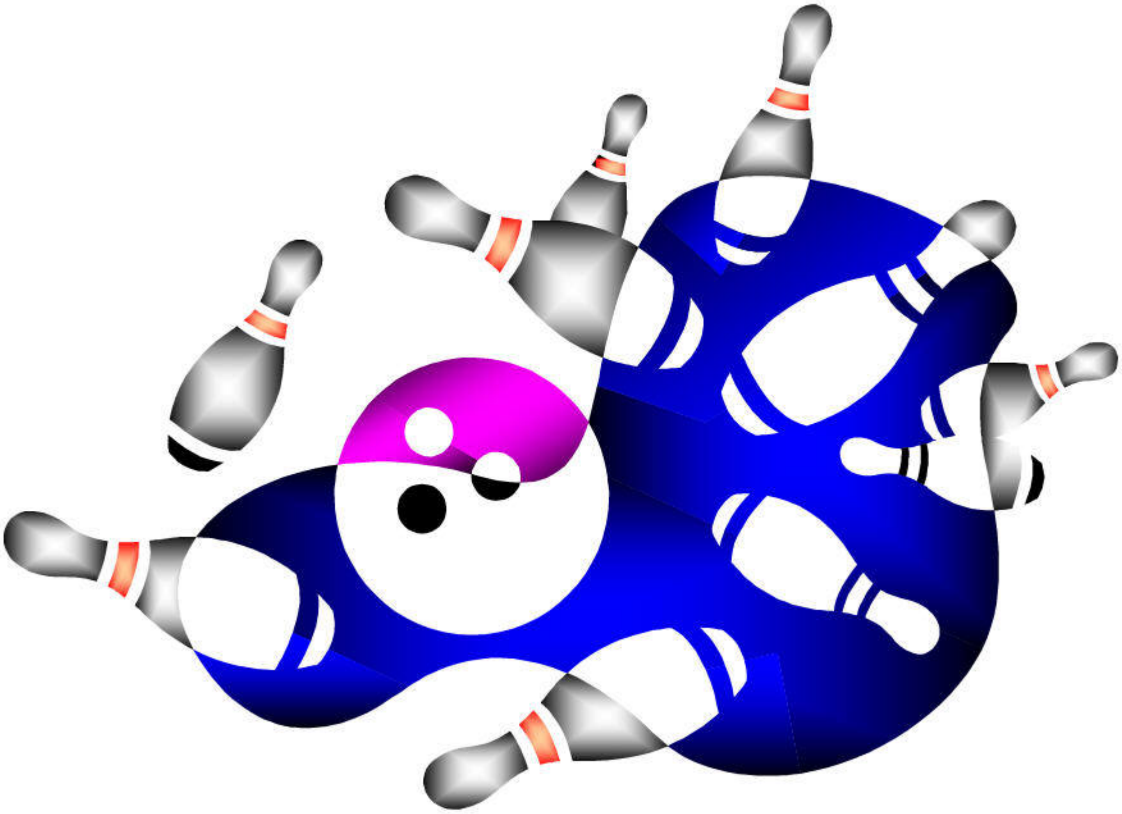
Table 1: Radius of Gyration Values [6,7]

Rg Value (in)	Rg Rating	Typical Reaction
2.43 – 2.48	Very low	Very early arcing break point
2.49 – 2.51	Low	Early and strong arcing break point
2.52 – 2.54	Medium – Low	Medium length with snapping break point
2.55 -2.58	Medium	Gets down lane easily with snapping backend reaction
2.59 – 2.66	Medium – high	Late break point with sharp or arcing break point depending on carrydown
2.67 – 2.80	High	Extremely late break point

Figure 4: Example ball cores that will or have been extracted and will be tested on the rotational dynamics platform. Theoretical calculations based on the 3-dimensional core shape will also be conducted and compared to the experimental results.

Table 2: Differential Radius of Gyration Values [6,7]

For the differential radius of gyration values, the larger the value of the differential the sooner the ball will hook due to increased friction. For example, radius of gyration and differential radius of gyration information on the selected bowling balls can be found at http://lane1bowling.com/tech/differential.html.[8] It will be interesting to explore the results of our core calculations and experimental results in comparison to the manufacturers published information about particular whole bowling balls (core, mold, and cover).



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