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Independent Study: Dimples and Rotation of Golf Ball

For my Independent Study, I furthered my analysis of the motion of a Golf Ball. First by adding the effects of dimples. Golf Ball dimples have an effect on both the final distance and initial angle of the ball. This is due to the dimples reducing the drag force coefficient and thereby reducing the drag force. In Giordano and Nakanishi textbook, *Computational Physics (45),* the dimples effect on the drag coefficient can be approximated as:

$$Cd = 7.0/V$$

- *However, if the velocity (V) is less than 14 m/s, then Cd is still approximated as 0.5*

By integrating this as an if-statement into the code, a more realistic model is made, with final distances of roughly 215 m and an initial angle of 9.1 degrees, which is now comparable to the 9 degrees and 215 m found in the textbook (45).

Now with a more realistic model of a golf ball, new shots can be added for shots in the z-direction as well, like a hook or slice. These are caused by an angular velocity on the ball in the x-direction and z-direction. The initial velocity of the ball in the z-direction will be approximated to be the angular velocity in the z-direction times the radius:

$$Vz = \omega_z * R$$

The forces acting on a golf ball are still the same, so by studying the relationship between the angular velocity and the acceleration of the ball, it can be seen that the acceleration in the x-direction is proportional to the angular velocity in the z-direction and the acceleration in the z-direction is proportional to the angular velocity in the x-direction. This is due to the magnus force which is the cross product of the angular velocity and linear velocity.

In this case, the angular velocity will be assumed to have only an x and z-component and the magnus coefficient will be kept constant. It was approximated at 0.00006 after working backwards with the value for So from *Computational Physics (45)* which is equal to the magnus coefficient*angular velocity, divided by the mass. The magnus force is given by:

$$Fm_x = So * (-\omega_z * V_y)$$

$$Fm_z = So * (\omega_x * V_y)$$

In this model, the angular velocity has a direct impact on the force and after running a loop, a desired final position can be found. The loop obtains a minimum first for the spin in the z-direction, for the desired final position in x plane. Then using that spin, the spin in the x-direction will be augmented and judged based on what effect that change will have on the x-position. Despite the different equations, there is still a relationship between them, the loop ends once the desired z-position is obtained and the final x-position is still the same.

In this case, validation is more difficult, but the results very useful. This could tell golfers what speeds and spins they're looking for, in a desired golf course. Of course, more modifications need to be made as the code only works for slices and pushes. With an initial speed of 70 m/s, and a desired distance of 300 m in the x-direction and 50 m in the z-direction, an optimum spin is 126 in the x and 72 in the z. This is in radians/sec and when converted to rpm, the value is 1206 rpm. This is of course smaller than the normal spin on the ball seen which is somewhere in the 2000.

This is due to the average spin being calculated as spin that produces farthest overall distance and not a desired distance. The average shots of golfers from the PGA tour reach spins of 2685 rpm. Which allows them to travel much farther distances. This code works more for optimum speeds an angles for exact desired distances. Those shots taken to gather those values were all about maximizing final distance in general. With this code to find optimum spin

Works Cited

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