Computational Physics Project 3

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1 Baseball Pitching

1.1 Introduction

To model the motion of a baseball, we take realistic measurements from our hypothesized baseball game to extend our previous cannonball model into three dimensions. Our baseball model uses air resistance calculated via the discussed equation with the isothermal altitude dependence. We also include the Magnus force generated via the ball's pitched spin. The constant, initial, and final values were given in imperial units, thus we converted them to SI units.

- Field altitude: 5280 feet = 1609.344 meters
- Distance from pitcher to homeplate: 60.5 feet = 18.44 meters
- Initial speed: 70 miler per hour = 31.2928 meters per second
- Height of ball when thrown: 5.2 feet = 1.585 meters
- Initial distance of the ball from the center-line: 1.1 feet = 0.335 meters
- Headwind speed: 5 miles per hour = 2.235 meters per second
- Final height of ball: 0.90 meters (as given)
- Final distance of the ball from the center-line: -0.10 meters (as given)

Note that the final height of the ball is the final y value and the final distance of the ball from the center-line is the final z value.

1.2 Methods and Results

From the model of a cannonball, numerous adjustments were needed to model the trajectory of a baseball. The first adjustment we made was to solidify the air resistance model and gravity adjustment by taking away the input factors introduced in the cannonball model. Constant gravity was used. This change improved efficiency and readability of the code. Next was to implement the varying drag coefficient,

$$\frac{B_2}{m} = 0.0039 + \frac{0.0058}{1 + e^{(v - v_d/\Delta)}}.$$

Introducing the z-direction to the code was next. This involved updating all subroutines to include the z-position and z-component of the speed. Note that, in the Euler method calculation for the change in speed, the change in the z-speed is equal to $-F_{\text{drag}} \cdot v_z - F_{\text{Magnus}}$.

The last change that was made was in testing methods. The strategy implemented in this model was first to acquire the firing angle that achieves the desired final height, then to acquire the ball spin rate causing the ball to land in the desired distance from center. Firing angles were tested in steps of $0.001°$ and ball spin rates were tested in steps of 0.1 radians per second. The firing angle that resulted in a final height of 0.90 meters is $3.666°$ and the ball spin rate that resulted in a final displacement from the centerline of -0.10 meters is 186.5 radians per second.

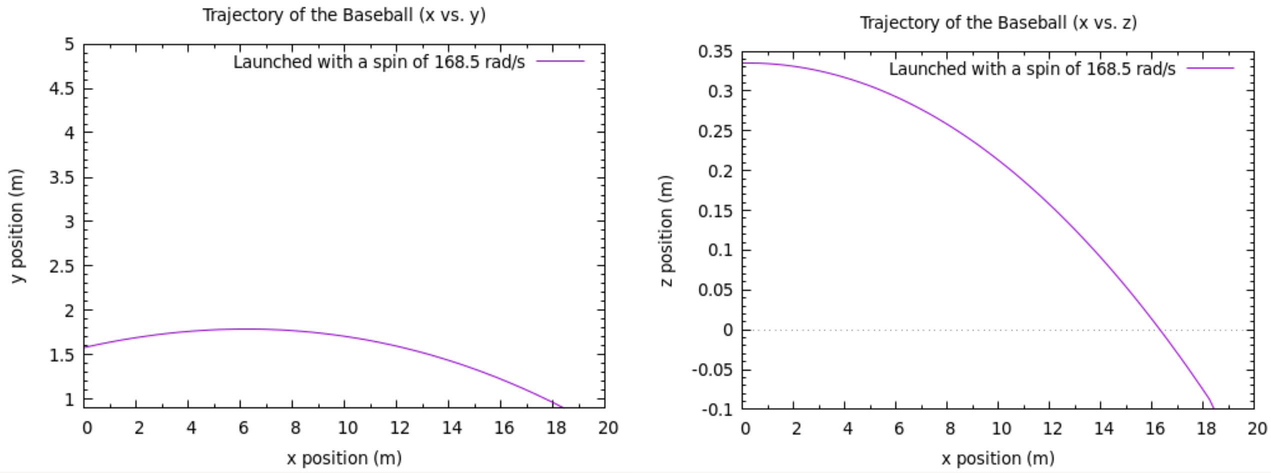

Figure 1: $3.666°$ Firing Angle and 186.5 rad/s Ball Spin

1.3 Conclusion

We developed a three-dimensional model of the trajectory of a baseball under altitude-dependent air resistance and including the Magnus force from the rotation of the ball. To reach the desired $x_{\text{final}} = 18.4404$ meters, $y_{\text{final}} = 0.90$ meters, and $z_{\text{final}} = -0.10$ meters, a firing angle of $3.666°$ and a ball spin of 186.5 radians per second were found. The firing angle is reasonable when taking into account how real baseball players throw the ball close to parallel to the ground. The ball spin rate of 186,5 radians per second equates to 1,780.9 rotations per minute, or 29.68 rotations per second. This is a high spin rate, but one that is reasonable for professional baseball pitchers[1].

1.4 Sources

1 Understanding Rapsodo Pitching Data: Spin Rate Efficiency Profile (Curveball, Slider, Changeup), https://rapsodo.com/blogs/baseball/