Aerodynamics of a Frisbee

Term Project of Classical Mechanics

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1 Introduction:

The fascinating aerodynamics of a Frisbee contribute to its unique flight characteristics. Composed of lightweight materials, typically plastic, a Frisbee is designed with a slightly concave shape. This shape, coupled with a beveled edge, enables the Frisbee to generate lift as it spins through the air.

When thrown, the spin imparts gyroscopic stability to the Frisbee, preventing it from wobbling and ensuring a smooth, predictable flight. The combination of the disc's shape, spin, and aerodynamic lift allows it to defy gravity and stay aloft for an extended period. As the Frisbee glides through the air, it seemingly hovers, creating a mesmerizing spectacle that captivates both players and spectators alike.

The beauty of the Frisbee lies not only in its flight characteristics but also in its versatility as a recreational tool. Beyond the traditional game of Ultimate Frisbee, people have invented numerous freestyle tricks, accuracy games, and distance contests that showcase the Frisbee's dynamic potential.

The simplicity of a Frisbee belies the complexity of its flight dynamics, making it a timeless and universally enjoyed pastime. Whether on a sandy beach, a grassy field, or a city park, the Frisbee's ability to soar effortlessly through the air adds an element of joy and playfulness to outdoor activities, creating memories and fostering camaraderie among friends and family. So, the next time you launch a Frisbee into the sky, take a moment to appreciate the harmonious dance between physics and fun that makes this iconic flying disc a beloved symbol of leisure and recreation.

2 Theory Of Firsbee Flight:

Aerodynamic lift, a fundamental principle behind the Frisbee's flight, can be elucidated through two major frameworks: Newtonian mechanics and the Bernoulli principle. Newton's third law of motion states that for every action, there is an equal and opposite reaction. In the context of a Frisbee, when the disc is thrown, the airfoil shape of the Frisbee's surface interacts with the air, creating lift as a reaction to the force applied. This lift is what allows the Frisbee to stay aloft and travel substantial distances.

The Bernoulli principle, a key concept in fluid dynamics, provides an alternative explanation for aerodynamic lift. As the Frisbee moves through the air, the air pressure on the upper surface decreases due to its curved shape. According to Bernoulli's principle, this decrease in pressure results in an upward force, contributing to the lift. Simultaneously, the lower surface experiences higher pressure, creating a combined effect that keeps the Frisbee airborne.

The gyroscopic effect plays a crucial role in stabilizing the Frisbee during flight. Gyroscopic inertia, derived from the conservation of angular momentum, ensures that the spinning disc maintains a stable orientation. As the Frisbee rotates rapidly, the angular momentum created by the spinning motion resists any external forces that might disturb its balance. This gyroscopic stability prevents the Frisbee from wobbling or tumbling in the air, allowing for a predictable and controlled flight path.

The harmonious interplay between aerodynamic lift and gyroscopic inertia transforms the simple act of throwing a Frisbee into a captivating display of physics in action. Whether it's a casual toss between friends or a competitive game of Ultimate Frisbee, understanding these underlying principles adds a layer of appreciation for the elegance and precision involved in the flight of this iconic flying disc.

2.1 Newtonian mechanics explains lift

2.1.1 Introduction:

In essence, Newtonian mechanics, relying on the concept of mass-flow rate (Force = ma = m/dt x dv), examines the forces generated by the airflow around the Frisbee's wing-like structure. When a Frisbee is in horizontal flight with a positive angle of attack (AOA), it moves through a static mass of air each second ('m/dt), accelerating it downward ('dv'). This downward acceleration results in a force (Force = ma = m/dt x dv), creating an equal and opposite upward force, which provides the lift necessary for flight. See Figure 1.

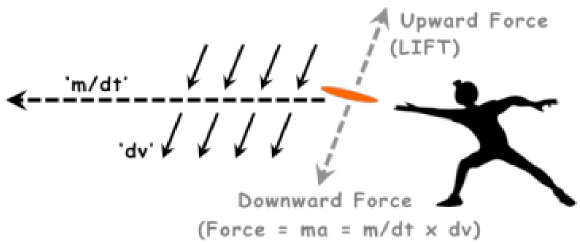


Figure 1: Forces and airflows on a frisbee. [1]

To delve into specifics, the lower side of the Frisbee pushes the air beneath it downward, while the curved upper side pulls the air above it in the same direction, aided by the Coanda effect. Understanding the Coanda effect is crucial, as it amplifies the amount of displaced air and, consequently, the lift generated. For optimal performance, a well-designed Frisbee maximizes the Coanda effect on its topside, influencing both its design and trajectory during flight.

The spin imparted to a Frisbee contributes to the stability of its flight through gyroscopic effects. This stability enables the Frisbee to produce smooth, laminar airflow, enhancing lift. It's important to note that the spin itself doesn't directly generate lift but plays a vital role in maintaining stable flight. Additionally, the intricate interplay of airflow vortices accounts for trick throws, where the Frisbee seems to defy conventional physics, adding an element of unpredictability and excitement to its aerodynamic performance.

2.1.2 Theory of Lift

The theory of lift based on Newton's laws of motion offers a straightforward and comprehensible explanation for the observed phenomena during the flight of a Frisbee. In essence, when a Frisbee is given a positive angle of attack (AOA), it induces a downward push on the surrounding air. In accordance with Newton's third law of motion, an equal and opposite force propels the Frisbee upward. It's noteworthy that during this process, the Frisbee also imparts a slight forward push to the air.(see Figure 2)

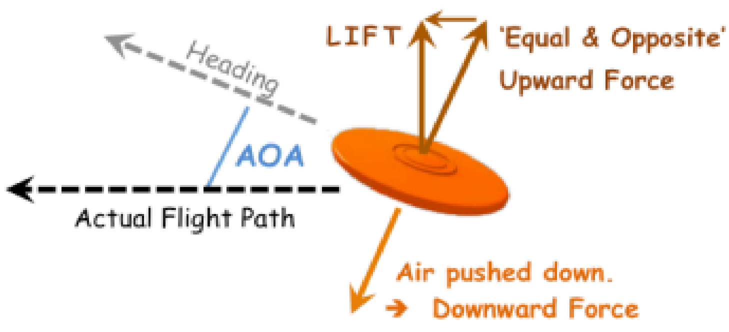


Figure 2: The key forces on a frisbee. [1]

The generation of lift involves two distinct airflows:

1. **Underside Airflow:**The lower surface of the Frisbee actively propels the lower air mass downward, resulting in the creation of high air pressure beneath the Frisbee (Pressure = Force $\times$ Area).

2. **Topside Airflow:** As the Frisbee advances, the curved upper surface induces a vacuum or an area of low air pressure. This vacuum effectively pulls the air above the Frisbee downward, a phenomenon aided by the Coanda effect.(see Figure 3)

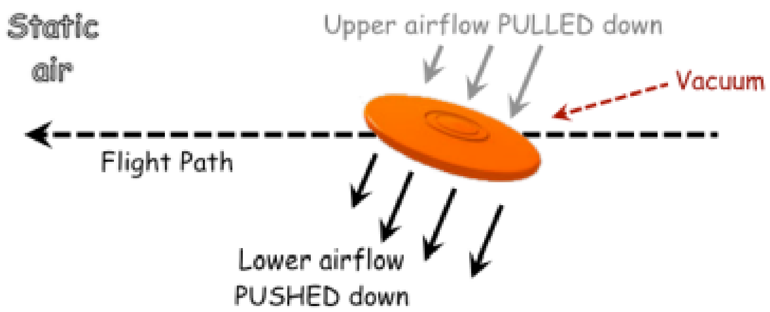


Figure 3: The two airflows on a frisbee. [1]

Newtonian mechanics provides a framework to explain the consequences of these airflows. Essentially, as the Frisbee moves forward, it traverses through a mass of static air each second ('m/dt') that it accelerates to a velocity ('dv') downward. This acceleration results in a downward force (Force = ma = m/dt × dv), as per Newton's second law of motion. Newton's third law then comes into play, generating an equal and opposite upward force. Lift, in this context, is the vertical component of this upward force.

Mathematically, these forces can be expressed by the following equations:

$$\text{Downward Force} = ma = \frac{m}{dt} \times dv \tag{1}$$

$$\text{Upward Force (Lift)} = \rho A v^2 (\text{Coef.}) \tag{2}$$

Where:

- m is the mass of the static air directly flown through.
- a is the acceleration (dv/dt).
- dt is the change in time (per second).

- dv is the change in velocity of the air.
- ρ is the air density.
- A is the effective wing area.
- v is the velocity of the air displaced down.
- **Coef.** represents the lift coefficient.

The Newtonian explanation of lift aligns with fundamental principles in physics, ensuring the conservation of momentum, mass, and energy. Momentum and energy are transferred from the Frisbee to the air, generating lift by pushing the air downward. This exchange results in a simultaneous descent of air and ascent of the Frisbee, with a concomitant decrease in air velocity.

2.1.3 Newtonian Mechanics and Angle-of-Attack (AOA)

The impact of the angle-of-attack (AOA) on both 'm/dt' and 'dv' is multifaceted [11], as depicted in Figure 1..

(i) In flight, Frisbees maintain a constant wingspan exposed to the direction of flight, effectively 'catching' air, regardless of the AOA. The wingspan is equal to the diameter of the Frisbee.

(ii) When a Frisbee is flown flat with a small AOA, it captures less air for each meter traveled. However, it can achieve higher speeds due to reduced drag, enabling it to 'catch' more air per second ('m/dt').

(iii) A low AOA exposes less disc depth (chord) to the air passing through, resulting in a slower displacement of air downward (lower 'dv'). Conversely, if the Frisbee is flying faster at this low AOA, it can more aggressively accelerate the air downward.

This interplay between AOA, air capture, and velocity highlights the dynamic relationship between Frisbee flight dynamics and the angle at which it is launched.

2.1.4 The Coanda effect on frisbees

The Coanda effect plays a pivotal role in shaping the physics of lift for frisbees. In the context of fluid flow, such as airflow around a frisbee, the Coanda effect naturally guides the flow along a curved surface. This phenomenon is akin to how falling water is redirected by a spoon, as illustrated in Figure 4 and Figure 5.

In broad terms, frisbees exhibit a pronounced Coanda effect at lower angles-of-attack (AOA) and higher airspeeds. Additionally, these conditions often coincide with reduced turbulence. The intensified Coanda effect primarily enhances the mass of air displaced downwards each second ('m/dt'), thereby contributing to lift.

The effectiveness of the Coanda effect is intricately tied to the maintenance of laminar (smooth) airflow. This, in turn, is influenced by factors such as the angle-of-attack (AOA), the frisbee's shape, and the stability of the disc in flight. Frisbees, with their curved top-side, minimize turbulence and maximize the amount of air displaced ('m/dt').

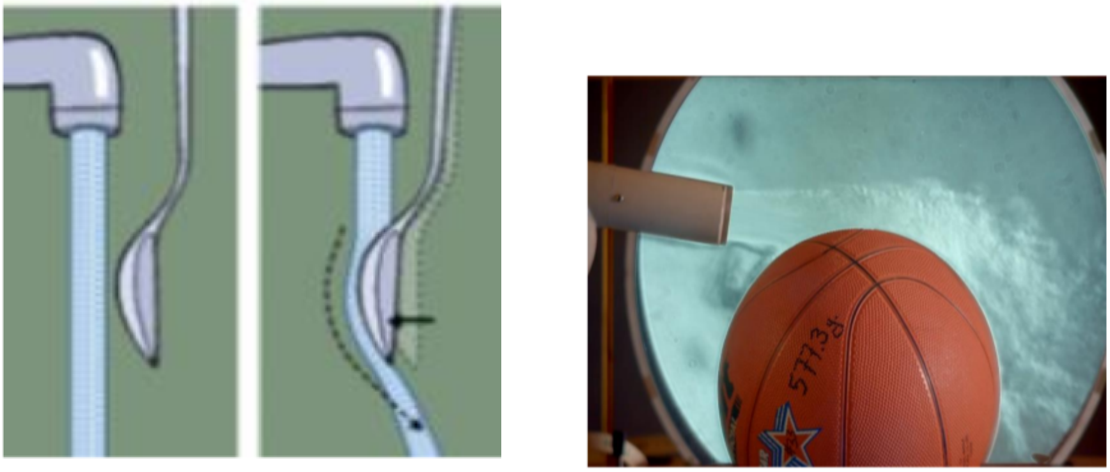


Figure 4: Example of Coanda effect. [1]

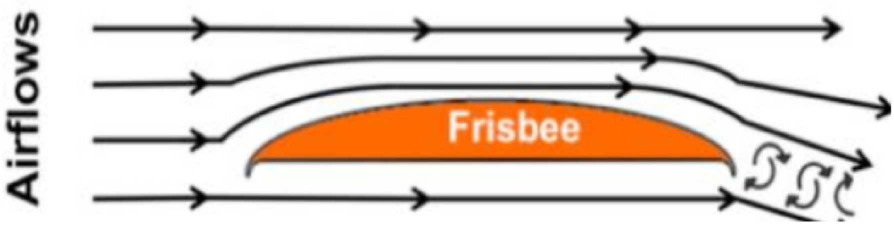


Figure 5: Illustration of the Coanda effect in frisbee flight. [1]

2.2 Spin and Stability in Frisbee Flight

The rotation or spin of a frisbee plays a crucial role in enhancing the stability of its flight, primarily attributed to the gyroscopic effects induced by the spin. This stability, in turn, enables the frisbee to generate lift effectively by maintaining laminar (non-turbulent) airflows. Refer to (Figure 6) for a visual representation.

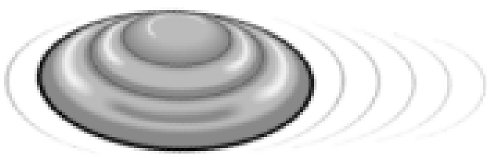


Figure 6: Spin on a frisbee. [1]

The frisbee's spin, by itself, does not directly contribute to vertical lift. However, the spin may facilitate the creation of vortices or induce a Magnus effect, generating a secondary force that can be employed for trick shots. It's important to note that this aspect is not essential for the primary purpose of lift.

2.3 Firsbee Trajectories:

Frisbee Trajectory and Throw Dynamics

Frisbees follow a curved trajectory (Figure 7) where lift and airspeed degrade gradually.

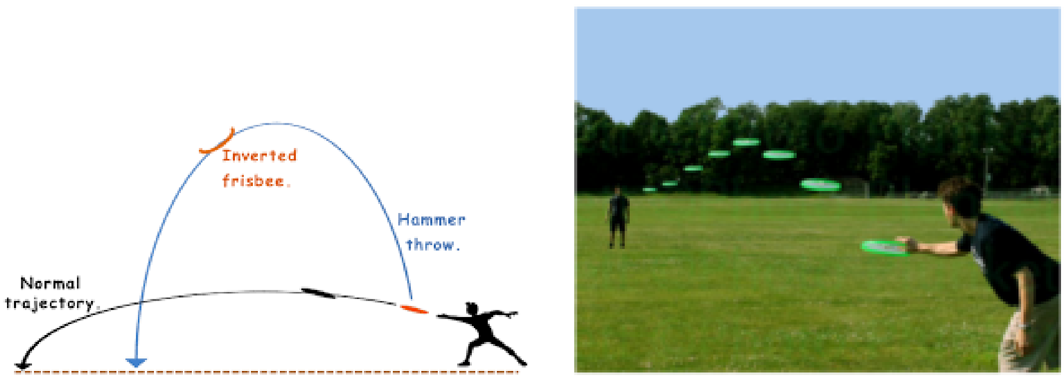


Figure 7: Typical frisbee trajectory. [1]

Newtonian mechanics explains why fast, nearly flat throws result in greater distance. Reasons include utilizing throw force for forward motion, maximizing the Coanda effect at a low angle-of-attack (AOA) for laminar airflow and reduced drag.

2.4 The physics of lift are debated

Strangely, the physics of lift remains debated due to the lack of anyconclusive evidence and realistic experiment to support any one theory
Broadly, there are two competing theories for lift:

- One camp claims that fluid flow over the topside of the frisbee sucks (pulls) it upwards. This is usually based on fluid mechanics (e.g. Bernoulli, Navier-Stokes or similar complex equations). or equation.
- The other camp claims that lift is the equal and opposite force resulting from the frisbee pushing air downwards, based on Newtons laws of motion. Newtonian mechanics provide universal and fundamental laws that explain the physics of how objects move. Using the mass flow rate is a new approach

2.5 Bernoulli's Principle and Frisbee Aerodynamics

The flight dynamics of a Frisbee hinge primarily on two aerodynamic forces: drag and lift. Determining the magnitude of these forces relies on specific physical relationships.

2.5.1 Drag force on frisbee

To ascertain the drag force, one must first establish the Reynolds number of the system. This value dictates the suitable drag equation to utilize. The Reynolds number is formulated as:

$$R = \frac{\rho v d}{\eta} \tag{3}$$

Here, ρ denotes the air's density, v represents the Frisbee's velocity in relation to the air, d is the Frisbee's diameter, and η stands for the air's viscosity. When examining a standard Frisbee launched at sea level, the air's density ρ is roughly 1.23 kg/m³, the typical velocity v is approximately 14 m/s, the accepted diameter d of the Frisbee is 0.260 m as endorsed by the National Ultimate Association, and the air's viscosity η is about 1.73×10^{-5} Ns/m². Consequently, this yields a Reynolds number of around 2.59×10^5. Given this Reynolds number magnitude, the Prandtl relationship is employed to compute the drag force, F_d.

$$F_d = -\frac{CD\rho\pi r^2 v^2}{2} = -\frac{CD\rho A v^2}{2} \tag{4}$$

The drag coefficient C_D is a characteristic of the Frisbee's design and structure. It is specifically influenced by the angle of attack α and is described as a quadratic function in relation to this angle.

$$C_D = C_{D0} + C_{D\alpha}(\alpha - \alpha_0)^2 \tag{5}$$

The constants C_{D0}, α_0, and $C_{D\alpha}$ are fixed values that are determined by the specific physical characteristics of the Frisbee.

2.5.2 Lift force on frisbee

The lift force is calculated using the Bernoulli principle. It states that there is a relationship between the velocity, pressure and height of a fluid at any point on the same streamline.

Mathematically

$$\frac{v_1^2}{2} + \frac{p_1}{\rho} + gh_1 = \frac{v_2^2}{2} + \frac{p_2}{\rho} + gh_2 \tag{6}$$

v = velocity of fluid; p = pressure of fluid; ρ = density of fluid; h = height of fluid Subscripts 1 and 2 denote different points.Height difference between the air flowing above and the air flowing below the frisbee is negligible ,also the velocity of the air flowing above is directly proportional to the velocity of the air flowing below because the difference in path length is constant(i.e. ρ_1 = Cρ_2)

$$\frac{C^2\rho_2^2}{2} + \frac{p_1}{\rho} = \frac{\rho_2^2}{2} + \frac{p_2}{\rho} \tag{7}$$

By equating $\frac{F_L}{A}$ to $p_1 - p_2$ (where F_L represents the lift force and A denotes the area of the Frisbee) and rearranging the equation, we can determine F_L.

$$F_L = \frac{1}{2}\rho v^2 A C_L \tag{8}$$

During the procedures to derive equation the coefficient C was integrated into the C_L coefficient. In Hummel's 2003 work, C_L is defined as a function that varies linearly with the angle of attack, α.

$$C_L = C_{L0} + C_{L\alpha}\alpha \tag{9}$$

C_{L0} and $C_{L\alpha}$ are constants determined by the inherent properties of the Frisbee

2.5.3 Gyroscopic Stability of Frisbee

Aerodynamic forces acting on a frisbee are not uniformly distributed across its surface. Specifically, the lift exerted on the front portion of the disc tends to be marginally greater than that on the rear portion. This disparity in lift creates a torque on the frisbee. Fortunately, the angular momentum generated by the frisbee's spin serves to counterbalance this torque. Without this spin, the frisbee's descent would resemble that of a drifting leaf, fluttering unpredictably as it descends. Therefore, a frisbee with a higher initial spin will exhibit a more stable and predictable flight trajectory. When a Frisbee isn't spinning, this small torque flips the front of the disc up, and any chance for a stable flight is lost. When a Frisbee is thrown with a large spin, it has a large amount of angular momentum that has a vector in either the positive or negative vertical direction. When the small torque is exerted, the torque vector points to the right side of the frisbee (when viewed from behind.)

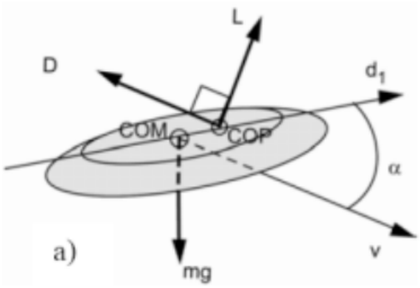


Figure 8: : Diagram of the off-center center of pressure (COP) and the center of mass (COM) that results in a torque exerted on the Frisbee [2]

This can be determined using the righthad rule with:

$$\tau = \vec{r} \times \vec{F} \tag{10}$$

since,

$$\tau = \frac{d\vec{L}}{dt} \tag{11}$$

The angular momentum vector of a spinning object, such as a Frisbee, tends to shift or ”precess” in a particular direction, typically to the right. This behavior is observable when examining a thrown Frisbee, leading many to notice that Frisbees often curve either to the left or right during their flight. As a result, when a Frisbee is endowed with a higher initial angular momentum, its flight trajectory becomes more consistent and stable.

3 Numerical Modelling of a Frisbee in Flight

A Python program was developed to simulate the trajectory of a Frisbee. This program utilized Euler’s method, integrating the forces previously detailed (refer to the Appendix for the code). For clarity, the forces acting on the Frisbee were categorized into horizontal and vertical components. Euler’s method was then separately applied to each of these components. It’s important to highlight that the simulation assumes the Frisbee starts with a sufficient initial spin to ensure its flight remains stable. In the implementation of Euler’s method, the Frisbee’s path was segmented into specific time intervals, denoted as Δt. At every such interval, the program recalculated the Frisbee’s horizontal velocity v and its corresponding horizontal position x.

$$v_{i+1} = v_i + \Delta v \tag{12}$$

$$x_{i+1} = x_i + \Delta x \tag{13}$$

where Δv and Δx are the changes in velocity and position respectively. A similar equation to equation () can be used with the vertical position, y, used instead of x. The Δv's are obtained by solving the following relationships:

Force equation in x direction:

$$F_x = F_D \tag{14}$$

$$m\frac{\Delta(v_x)}{\Delta t} = \frac{1}{2}\rho v_x^2 C_D \tag{15}$$

$$\Delta v_x = \frac{1}{2} m\rho v_x^2 C_D \Delta t \tag{16}$$

Force equation in y direction:

$$F_y = F_g + F_L \tag{17}$$

$$m\frac{\Delta(v_y)}{\Delta t} = mg + \frac{1}{2}\rho v_y^2 C_L \tag{18}$$

$$\Delta(v_y) = (g + \frac{1}{2m}\rho v_x^2 C_L)\Delta t \tag{19}$$

where the subscripts x and y denote the horizontal and vertical velocity respectively and F_g is the force of gravity. Δx and Δy are simply stated as,

$$\Delta x = v_x \Delta t \tag{20}$$

$$\Delta y = v_y \Delta t \tag{21}$$

$C_{D0} = 0.08$, $C_{D\alpha} = 2.72$, $C_{L0} = 0.15$, $C_{L\alpha} = 1.4$ Initial velocity along x-axis, y-axis, and angle of attack measured using tracker software.We used a standard frisbee with a mass of approximately 175g and diameter = 26 cm take that data from .

4 Experiment Procedure and Observation

During our trials of throwing Frisbee, we tried with different initial angles by our guess as we had no Frisbee launcher where we can set exact initial angle of attack of Frisbee. In this experiment we had no control on the initial velocity of Frisbee as we thew it by hand. We captured each throwing video and tracked them using tracker software. After tracking Frisbee of those videos we got trajectory of Frisbee, initial angle of Frisbee and initial velocity of Frisbee in x and y direction. Then we choose 6 videos with different initial angle of attack with highest of 46.6 degree and lowest of 8.6 degree.

After that, using those initial conditions in the theory of Frisbee based on Bernoulli's principle we simulated motion of Frisbee on python to see whether Theoretical prediction matches with Experimental result or not.

Physical Conditions: Still air, air density = 1.23 kg/m^3, g = 9.81m/s, mass of Frisbee = 175gm, Area = 568 cm^2

4.1 Experimental and Theoretical Trajectory

Here we provide experimental trajectories using Tracker software and also Theoretically predicted trajectories, along with graphs of some relevant quantities (like x, y, v_x,t, etc).

4.1.1 Experiment 1

For initial height of Frisbee = 1.207m, initial velocity along x component = 8.113 m/s, initial velocity along y component = 4.630 m/s, initial attacking angle = 29.7 degree:

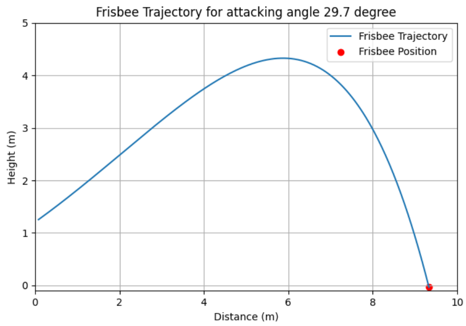


Figure 9: Trajectories of Frisbee, Left side is experimental trajectory and Right side is Theoretically predicted trajectory [4]

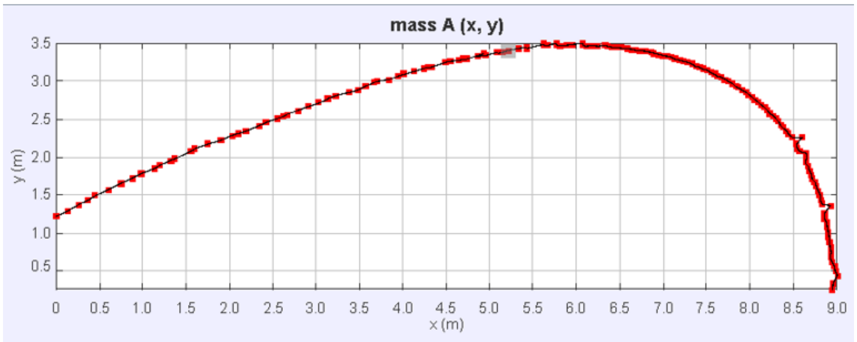


Figure 10: Experimental result for x vs y

According to theoretical prediction the range covered by Frisbee and maximum height of the Frisbee is respectively 9.32m and 4.34m where experiment shows that range and maximum height is respectively almost 9m and 3.5m which is so close to the theoretical prediction.

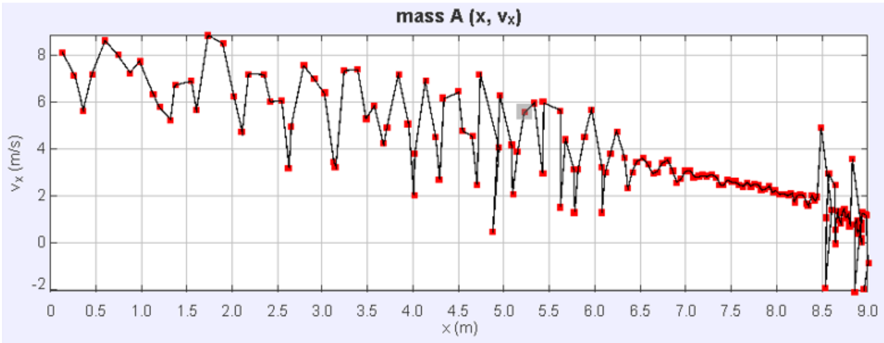


Figure 11: Experimental result for v_x vs x

We know for simple projectile motion v_x remain constant with x but above figure shows that v_x decrease with x, which is because of complicated aerodynamic motion of Frisbee.

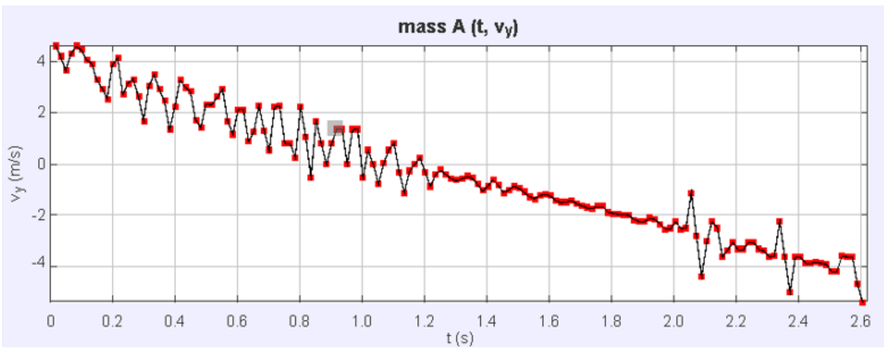


Figure 12: Experimental result for v_y vs t

Here we see our expected graph, vertical velocity of Frisbee decreases to zero while Frisbee at its maximum height, then it gain its vertical velocity in opposite direction with time.

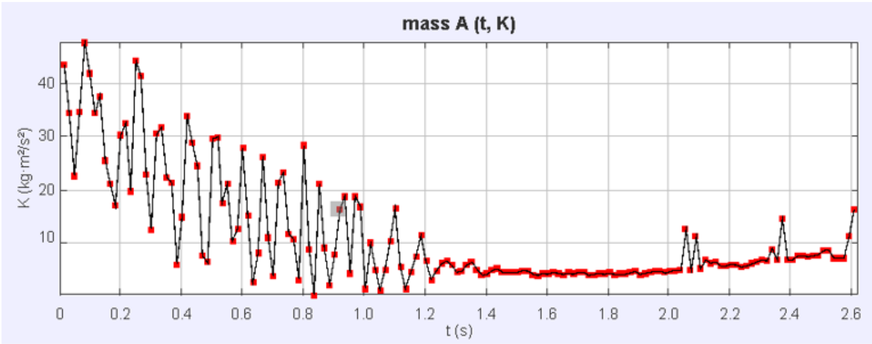


Figure 13: Kinetic Energy vs Time

Above graph shows that the kinetic energy of Frisbee decreases with time due to air drag, and it goes to minimum when Frisbee reaches to the ground.

Remarks: In every graph except trajectory, we got some fluctuation which is because when we track the Frisbee, due to its wobbling motion, we manually track Frisbee for some distance.That's how we got fluctuations in graph.

Similarly we repeat this experiment for with various angle in a decreasing order, shown below:

4.1.2 Experiment 2

For initial height of Frisbee = 1.407m, initial velocity along x component = 13.895 m/s, initial velocity along y component = 2.84 m/s, initial attacking angle = 21.8 degree:

Figure 14: Experimental trajectory of Frisbee

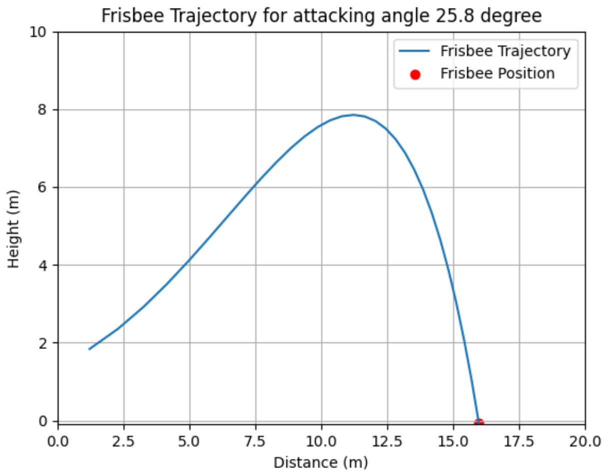


Figure 15: Theoretically predicted trajectory of Frisbee [4]

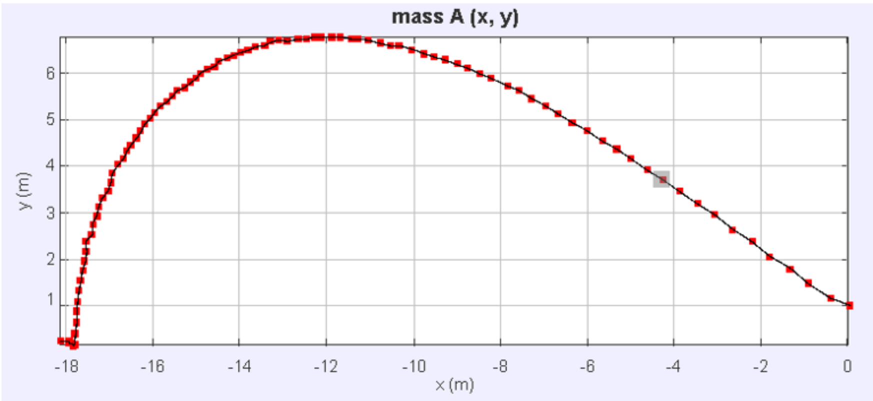
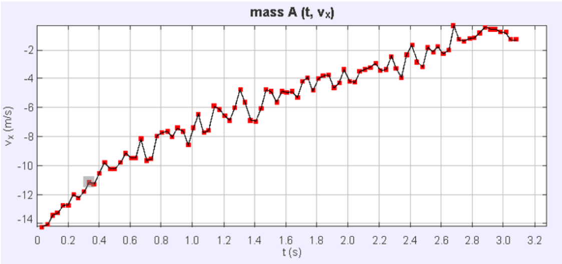


Figure 16: Experimental result for x vs y

This is another experiment where we aging get almost same value of maximum height and range of Frisbee for theoretical prediction and experimental result.

- Range from theoretical prediction = 16m
- Range from experiment 17.6m
- Maximum height from theoretical prediction = 7.9m
- Maximum height from experiment = 7m



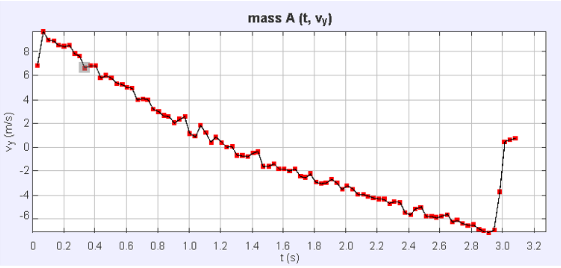


Figure 17: Experimental result for v_x vs t (left side) and v_y vs t (right side)

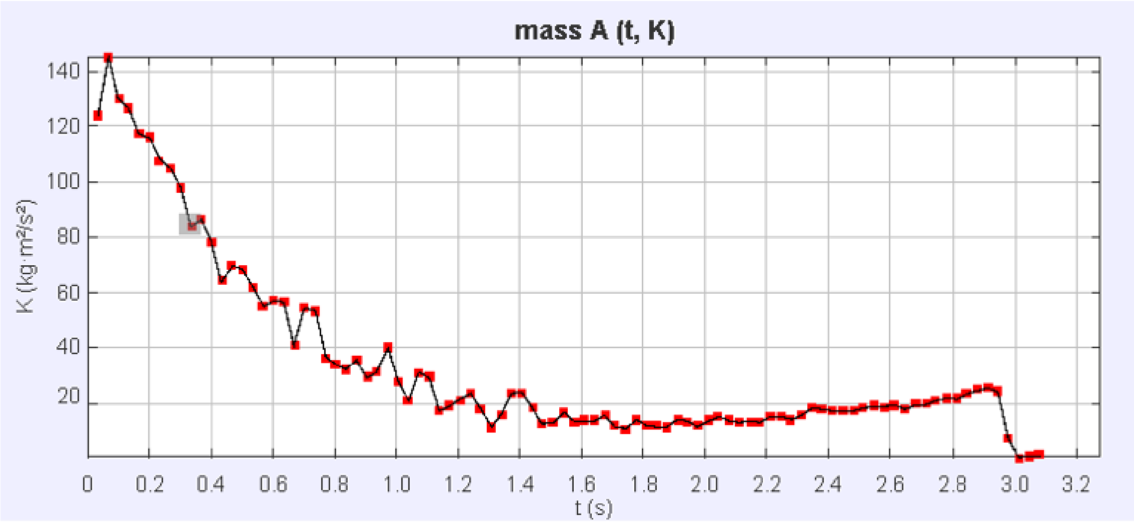


Figure 18: Experimental result for Kinetic energy vs time

Above three figure shows the same result as we got from experimental result.

4.1.3 Experiment 3: Difference from projectile motion

For initial height of Frisbee = 1.609m, initial velocity along x component = 11.23 m/s, initial velocity along y component = 6.545 m/s, initial attacking angle = 30.2 degree:

Figure 19: Experimental trajectories of Frisbee

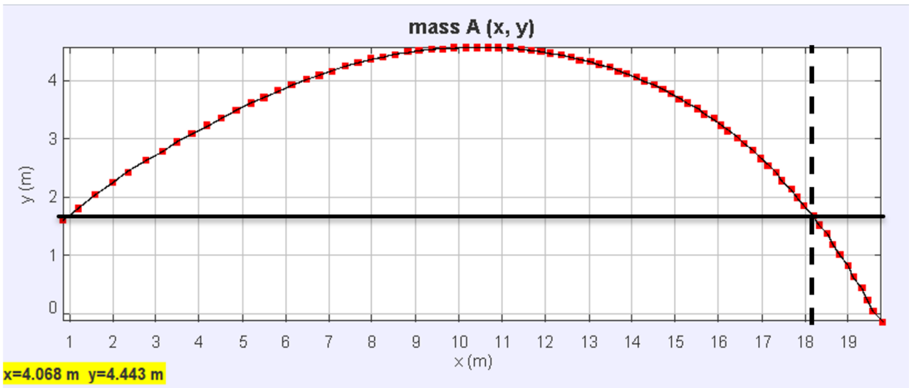


Figure 20: Experimental result for x vs y

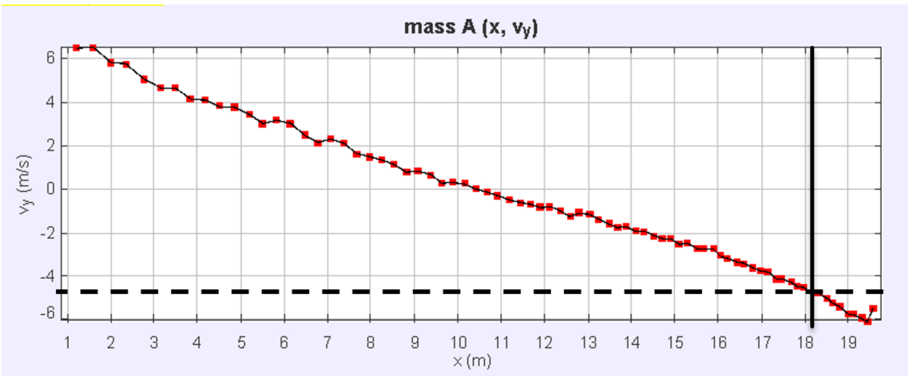


Figure 21: Experimental result for v_y vs x

In Experiment 1 we showed that v_x is not remain constant, which is a difference of Frisbee motion from normal projectile motion. Here in Experiment 3 we see that when we release the Frisbee, its velocity along y component is 6.545 m/s, after travelling 18.2m horizontally Frisbee reaches its original height and its velocity along y components at that position is not same as initial v_y, rather it decreases to 4.8 m/x, which is another difference of Frisbee motion from normal projectile motion.

4.1.4 Experiment 4

For initial height of Frisbee = 1.227m, initial velocity along x component = 9.143 m/s, initial velocity along y component = 2.528 m/s, initial attacking angle = 15.5 degree:

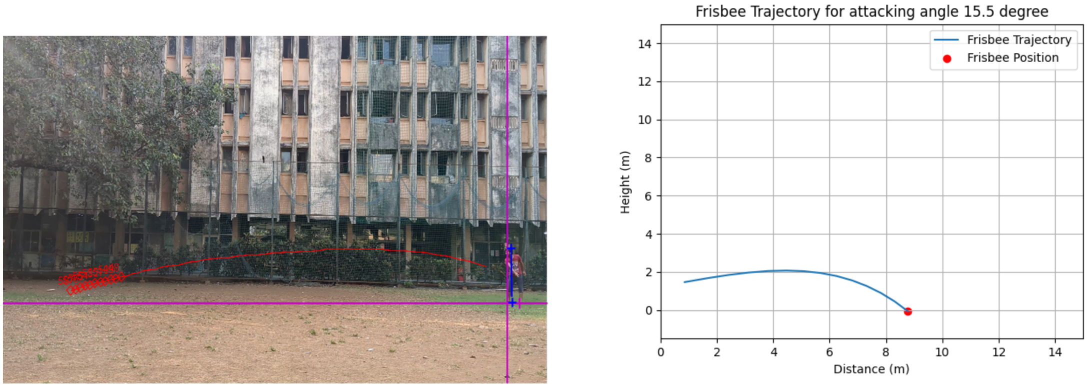


Figure 22: Trajectories of Frisbee, Left side is experimental trajectory and Right side is Theoretically predicted trajectory [4]

Experimental results are following:

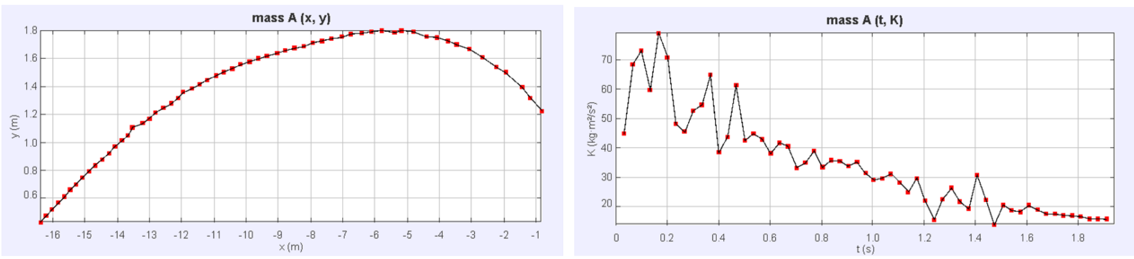


Figure 23: Experimental result for x vs y (left side) and Kinetic energy vs t (right side)

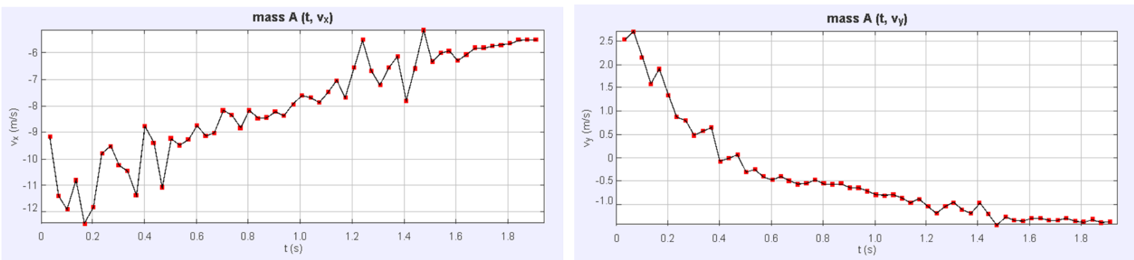


Figure 24: Experimental result for v_x vs t (left side) and v_y vs t (right side)

4.1.5 Experiment 5

For initial height of Frisbee = 1.275m, initial velocity along x component = 10.72 m/s, initial velocity along y component = 1.621 m/s, initial attacking angle = 8.6 degree:

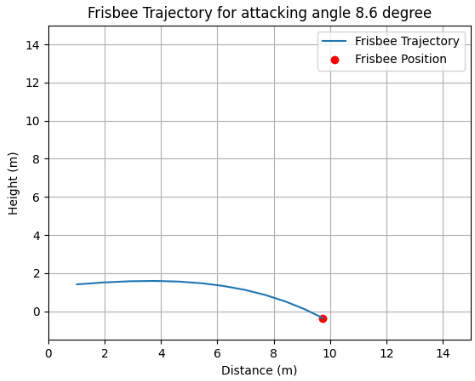


Figure 25: Trajectories of Frisbee, Left side is experimental trajectory and Right side is Theoretically predicted trajectory [4]

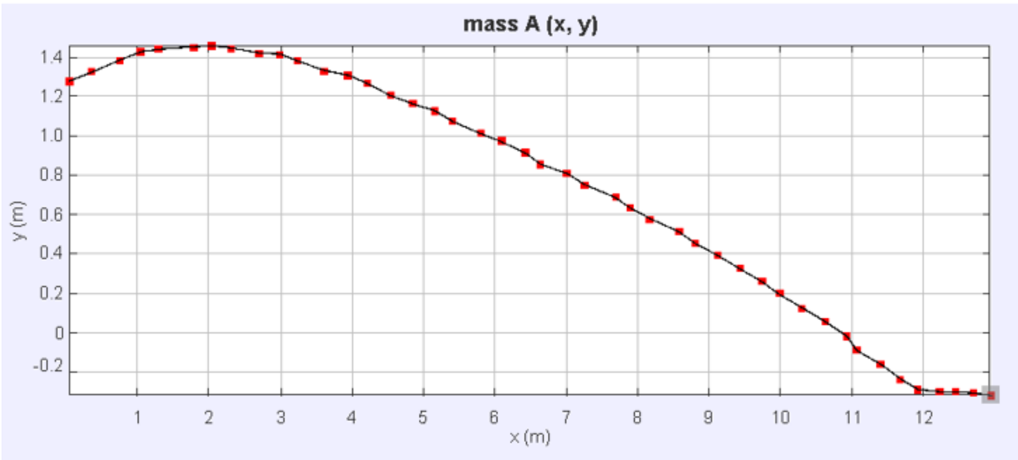


Figure 26: Experimental result for x vs y

Above graph shows:

- Range from theoretical prediction = 9.3m
- Range from experiment 11.9m
- Maximum height from theoretical prediction = 1.64m
- Maximum height from experiment = 1.46m

Another experimental results are following:

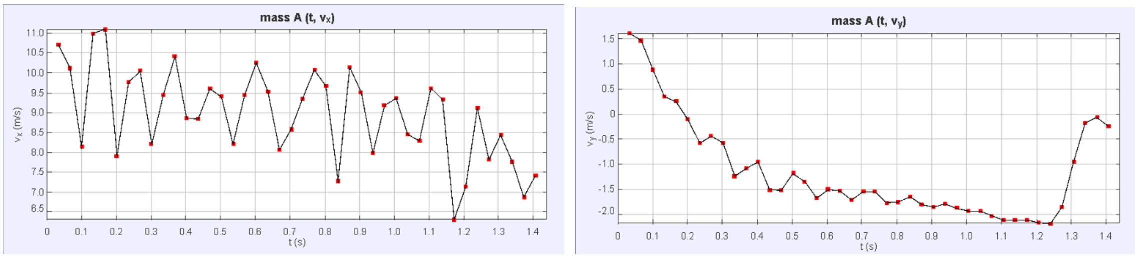


Figure 27: Experimental result for v_x vs t (left side) and v_y vs t (right side)

Remarks: In some graph we can see that x or y velocity component or kinetic energy suddenly rises as Frisbee hits the ground, which is due to the conversion of spinning motion of the Frisbee to translational motion after it hits the ground.

4.1.6 Experiment 6: Deviation from theoretical prediction

For initial height of Frisbee = 1.659m, initial velocity along x component = 8.379 m/s, initial velocity along y component = 8.846 m/s, initial attacking angle = 46.6 degree:

Figure 28: Trajectories of Frisbee, Left side is experimental trajectory and Right side is Theoretically predicted trajectory [4]

- Range from theoretical prediction = 9.46m
- Range from experiment 11m
- Maximum height from theoretical prediction = 12.7m
- Maximum height from experiment = 5.6m

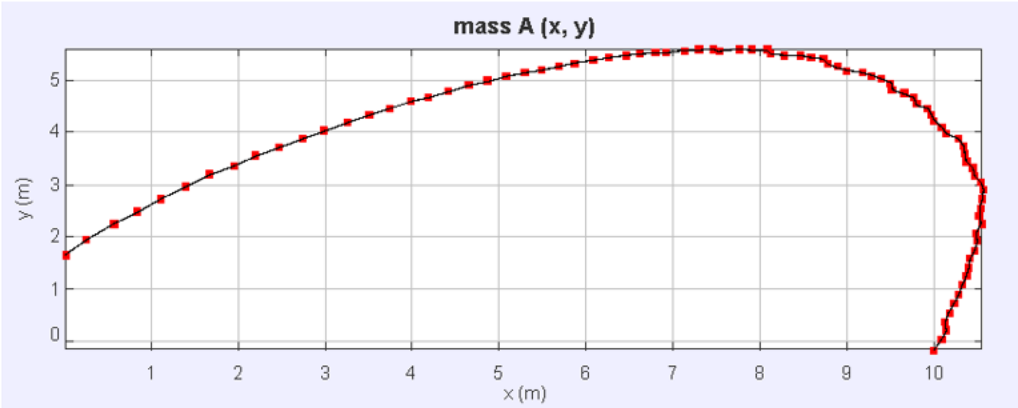


Figure 29: Experimental result for x vs y

This experimental results claims that theoretical prediction is incorrect for large initial angle of attack of Frisbee, which a limitation of the the theoretical algorithm.

5 Conclusion

Understanding the intricate dynamics of Frisbee flight has unveiled a fascinating world of aerodynamics and mechanics. Through this project, we've delved into the forces governing its trajectory, spin, and stability, unraveling the secrets behind its graceful flight. The blend of scientific principles and real-world experimentation has not only enriched our comprehension of flight dynamics but has also amplified our appreciation for the simplicity and elegance of this everyday flying disc.

Yet, even as we draw this project to a close, our exploration merely scratches the surface of what lies ahead. A lot of factors such as wind velocity, air density, angle of attack, initial velocity, mass of frisbee, thickness of frisbee edges etc have their own effects on frisbee flight. In future, further research may include developing a three dimensional model that includes the precession and rolling of the frisbee, as well as looking into various physical properties of the frisbee.

References

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[4] Git hub link– https://github.com/Dibakar2020/CM_Project.git