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### X-zyLo (Flying Toy)

X-zyLo is the incredible flying gyroscope that has been thrown the length of two football fields.

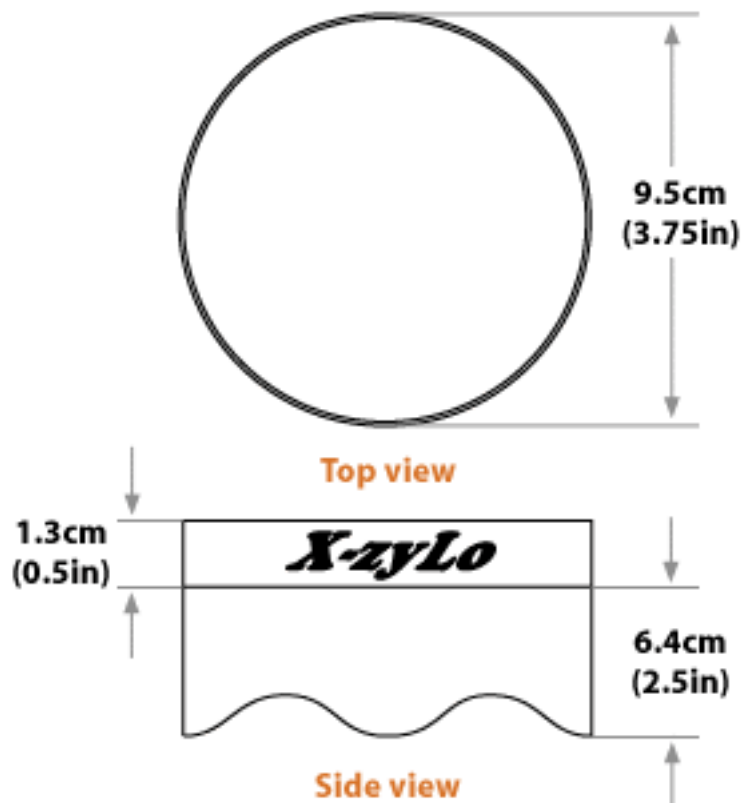
It's a deceptively simple looking toy that can fly 600 feet (183 metres).

Thrown spirally like a football, the X-zyLo becomes a flying gyroscope, resisting gravitational torque (force) and random air current torques.

The cylinder's leading edge is thicker, so the upper and lower surfaces act as airfoils to provide lift. Made in USA.

The X-zyLo has flown onto the outdoor recreational scene as one of the most exciting games of catch. It was invented by Mark Forti, a Baylor University student, and refined within the aerospace industry. X-zyLo met with immediate acclaim and was rated as the best flying toy in a Massachusetts Institute of Technology (MIT) field test. X-zyLo unofficially broke the existing world flying disc distance record when it was thrown 655 feet (199.6 metres).

NASA scientists, renowned aerospace engineers and academic institutions have met with the makers of the X-zyLo, The William Mark Corporation, and studied X-zyLo's fascinating flight technology. Yet no consensus has been reached on how X-zyLo actually flies..



### Throwing Instructions

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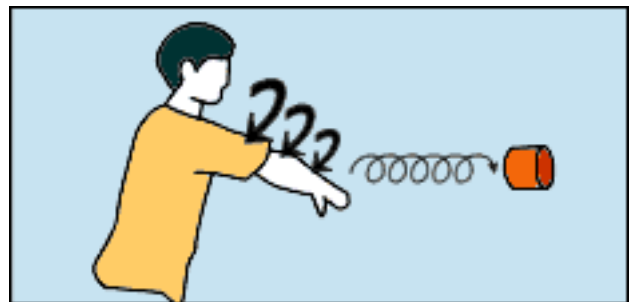
X-zyLo loves to fly and needs a lot of room. So learn how to throw X-zyLo in an open area such as a park or field. For first throws, the catcher should be at least 30 to 60 yards (25 to 55 metres) away.



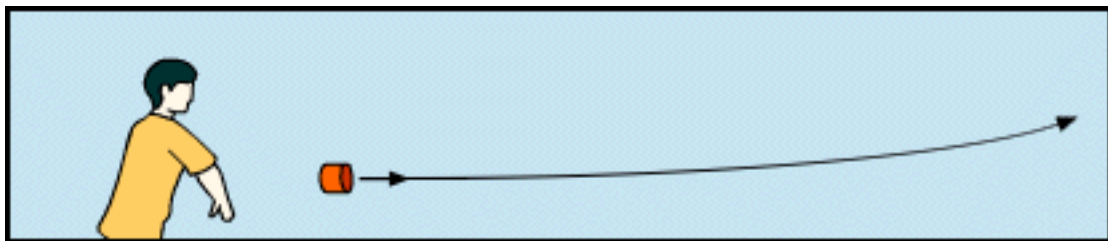
Grip X-zyLo like a football with the ring forward and open to the direction of flight.



Whip X-zyLo fast and low. Throw forward like a football quarterback or a baseball pitcher. Rapid spin is critical to its flight.



Do not throw X-zyLo high or tilt it upwards because X-zyLo creates its own lift. The Low throws go further:



#### Remember:

The only two rules for throwing X-zyLo are that you have to get it spinning fast and moving forward. A great thing about X-zyLo is that you can throw it all sorts of ways.

**Hint:**

Here's a really great tip. Right handers first throws tend to be high and to the right. To aim straight, throw fast, low and to the left (left handers should throw low and to the right). Also, right-handed throws curve left at the end, so judge for the curve when catching.

**Safety First:**

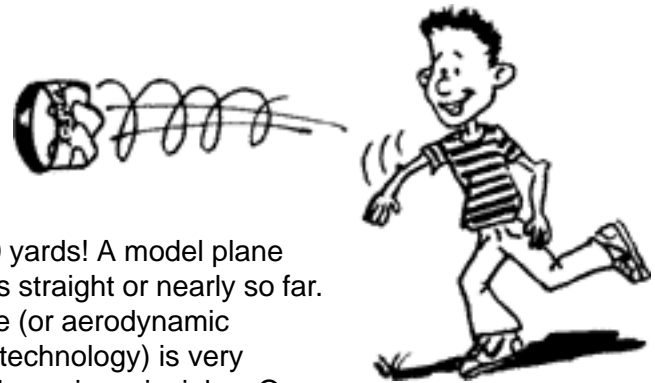
Remember to throw clear of bystanders and throw only as hard as the catcher's distance warrants. Hard throws to someone close may hurt.

**X-zyLo: Aerodynamic and Gyroscopic Principles**

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**1. Introduction**

X-zyLo is an astonishing flying gyroscope that has fascinated people of all ages and intrigued scientists with its superb flight characteristics. X-zyLo flies very straight and very far. It weighs less than an ounce yet has been thrown over 200 yards! A model plane or airfoil of the same weight and size will not fly as straight or nearly so far. Most planes and airfoils fly because of their shape (or aerodynamic characteristics). The reason that X-zyLo flies (its technology) is very different. It flies due to both gyroscopic and aerodynamics principles. One can learn a lot about both of these principles while having fun playing with X-zyLo and comparing it with gyroscopes and airplanes.

**2. What will You Learn?**

By playing with and studying X-zyLo, you will learn all about the gyroscopic and aerodynamics technologies that make it fly. You will have great fun while becoming familiar with the terms science uses to describe them. They are (all terms are explained in this document):

*Aerodynamic Principles:*

- Bernoulli's Principle
- Dihedral
- Centre of Gravity
- Centre of Pressure
- Torque

*Gyroscopic Principles:*

- Angular Momentum
- Precession
- Inertia
- Centrifugal Force
- Centripetal Force

### 3. About X-zyLo

X-zyLo was invented by a Baylor University student in 1991. You will observe that it consists of a thin, heavy ring (the gyro) that measures 3.75in (9.5cm) in diameter and 0.5in (1.3cm) wide and a light, thin cylinder (the wing) that is approximately 2.5in (6.4cm) long. It is straight on the "leading" end and curved or "scalloped" on the "trailing" end. X-zyLo weighs 25 grams - less than one ounce (28 grams). This deceptively simple device commonly flies in excess of 100 yards (90m) when correctly thrown. X-zyLo's world record throw is 218 yards or 655 feet (199.3m)! Nothing so light has ever been thrown so far.



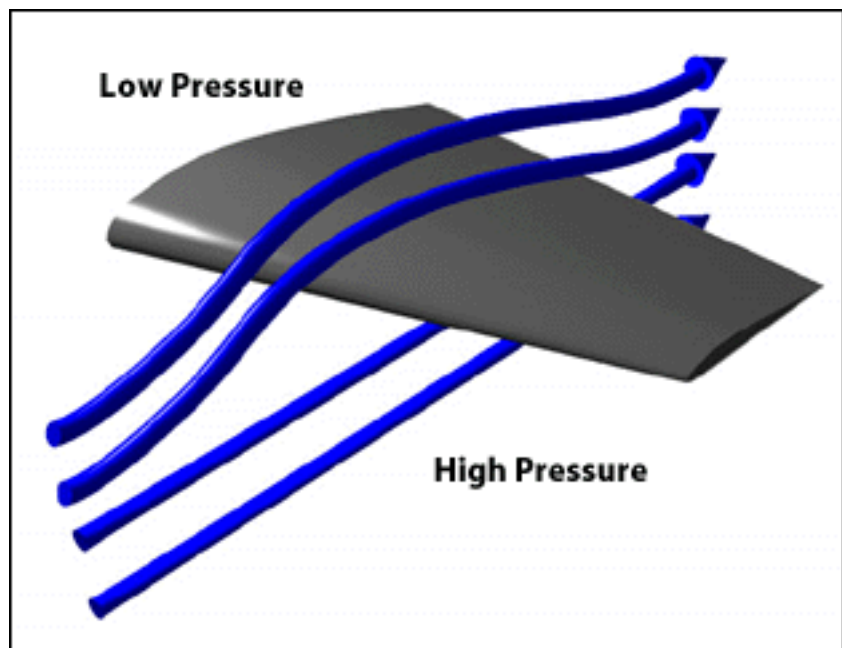
### 4. What Makes Planes Fly? Bernoulli's Principle and Dihedral

Planes fly because of their aerodynamics. **Aerodynamics** is the study of air as it moves around objects.

A wing flies because of its cross sectional shape. In order to understand why a wing's shape is important we have to understand Bernoulli's Principle.

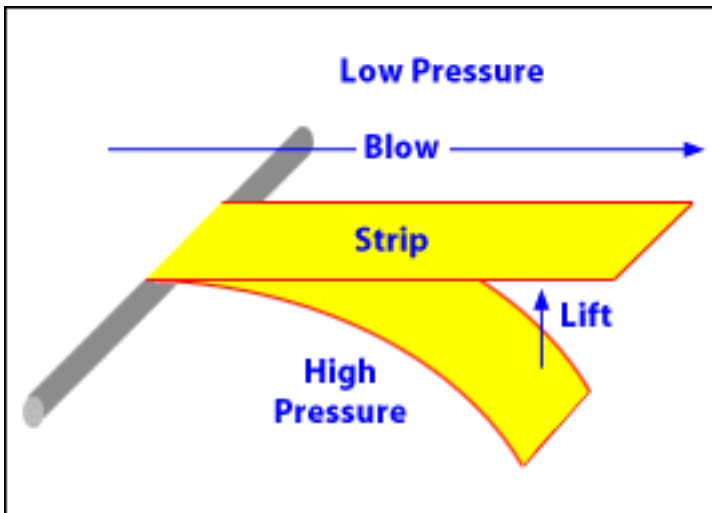
**Bernoulli's Principle** says that an increase in the velocity (speed) of air decreases the air pressure. Likewise, a decrease in flow velocity causes an increase in air pressure.

Low pressure is like a vacuum which pulls things toward it. A wing is curved on the top and flat on the bottom, as shown in the diagram:



So when a wing moves through the air, the air on top of the wing has to travel faster than the air under the wing. To say it again, because the wing is curved on the top, the air moving over the top must travel farther and faster than the air under the wing to get to the same place. This causes a decrease in pressure on the top of the wing. The pressure difference from the top and bottom of the wing causes a vacuum effect and the wing is pulled upward and lifts. The curve of the wing is called a **dihedral**. The body is often streamlined to provide the least amount of air resistance or drag possible.

To demonstrate the Bernoulli Principle try this simple experiment...



- Take a small piece of paper, about one inch wide and 10 inches long, and wrap it around a pencil so most of the paper hangs from the pencil away from you.
- Blow over the top of the paper as shown.

Which way would you expect the paper to move? Why did the paper move upwards instead of downward or stay in the same position? Does this confirm Bernoulli's principle?

Try another experiment. Observe the model airplane. Does its wings have a dihedral shape? Throw it and note its flight characteristics. Does it have lift? How far does it fly? Does it fly straight? Do you think Bernoulli's principle applies here?

Now fly X-zyLo. Does its' surface have the same shape as a plane's wing? Does it have lift? How far does it fly? Does it fly straight? Why is its performance in terms of both distance and accuracy far superior to that of an airplane wing with the same weight and surface area? We will address this later. First, we need to consider not only why objects have lift but also what keeps them stable in flight and prevents them from just tumbling all over the place.

## 5. Centre of Gravity and Centre of Pressure

Every flying object has what is called a **centre of gravity** and **centre of pressure**. The centre of gravity and centre of pressure must be in close proximity to one another in order for a wing to have a stable flight. The normal centre of gravity is a fixed point on the object where it is balanced by gravitational forces. To find the centre of gravity on X-zyLo, take a pen or pencil and move the tip up and down the underside of the top surface of the cylinder until you reach the point where the X-zyLo is balanced on the tip. This is X-zyLo's approximate centre of gravity. One of the purposes of X-zyLo's heavy front ring is to place its centre of gravity near its centre of pressure.

The centre of pressure on a wing is the point through which the most lifting pressure passes due to air flowing over it. Just as the centre of gravity on a wing is where gravity focuses its pull, the centre of pressure is where the air pressure focuses its lift on a wing.

Why must the curve of an airplane wing bulge in front rather than the middle or back of the wing? The reason is because the bulge in the front causes the centre of air pressure to be near or over the wings centre of gravity. In this way, the two forces hold the plane in place as it glides through the air. If the centre of pressure is not over the centre of gravity, but at some other point of the wing, it would push the plane over and cause it to tumble.

Can you guess where the centre of pressure is on the X-zyLo? It's where you located the centre of gravity - in the first 1/3 of the body. The weight of the ring causes the centre of pressure be near the centre of gravity?

Why does X-zyLo fly with a stable, straight, flight whereas the model plane does not? The answer lies in the fact that forces other than strictly aerodynamics are interacting with X-zyLo. Contrary to traditional planes, X-zyLo spins in flight and this spinning creates gyroscopic forces as we will next see.

Before we talk about gyroscopic forces, let's look more closely at X-zyLo's flight characteristics.

- A. Try to throw the X-zyLo backwards. Where is X-zyLo's centre of gravity when you throw it backwards? Where is the centre of pressure?
- B. Try to throw X-zyLo with absolutely no spiral (or spin). Is it stable? Does it fly straight? Does it fly predictably? Does it fly far?
- C. Now throw X-zyLo with rapid spin (remember fast and low). Why is it stable? Why does it fly in a straight line? Why does it turn left at the end of the flight? The answer to these questions has to do with spinning which is discussed below.

## 6. What is A Gyroscope?

A **gyroscope** is a spinning wheel or ring often mounted on a movable frame. When rapidly spun it stands straight up. When it is not spinning it is captured by gravity and falls down. Bicycles act as gyroscopes when they keep the bicycle straight up when the wheels are spinning. Also, tops act as gyroscopes when they stand straight up while rapidly spinning. Gyroscopes seem to defy the laws of gravity. By simply spinning, gyroscopes resist the forces of gravity. Gyroscopic forces probably were first recorded by Isaac Newton in the 17th century. Try this experiment with a gyroscope if you have one.

- A. Place the gyroscope with its axle straight up and down. Let go. If it's not spinning, it falls. Now get it spinning fast and place it with its axle straight up and down. It does not fall. Why? Now place the spinning gyroscope with its axle parallel to the table. Why does it stay that way?
- B. Place it on the end of your finger or on the edge of a drinking glass. Push it gently down. Does it fall?
- C. Now put your spinning gyroscope's axle parallel to the ground suspended on a string. It stays up but slowly turns. Why? This turning is called **precession**. We will learn more about that later.

As you can see, by spinning, gyroscopes produce a force that resists gravity, or any other force that tries to change its direction, and that keeps it stable. X-zyLo is really a spinning gyroscope with wings. Its spinning allows it to fly stably and straight in flight without nosing down. That's why it flies much straighter and farther than the model plane. To demonstrate this point another way, try the following:

- A. Hold X-zyLo parallel to the ground without spinning it. Let it fall to the ground. Which part of the X-zyLo hits the ground first?
- B. Now spin the X-zyLo parallel to the ground and let it drop to the ground. What part hits the ground first? Gravity tries to nose X-zyLo down (like it does with all "nose heavy" objects) yet when X-zyLo is spinning, it resists gravity from turning or **torquing** its nose toward the ground.

To understand reasons behind gyroscopic forces we need to know about **angular momentum** and **precession**.

## 7. Angular Momentum

The concept of "momentum" states that if any object is in motion it will continue to stay in motion in the direction it is moving unless another force acts upon it. Momentum equals the object's mass times its velocity or speed.

"Angular momentum" applies to objects that are moving in circles or spinning. In other words, they are moving "angularly" as opposed to a straight line. All spinning bodies exhibit angular momentum which is the measure of how fast the body is spinning, how much mass the body has, and how that mass is distributed.

The equation for angular momentum is:  $H=MR^2$  where M is the mass, R is the radius of the rim, and W is the spin velocity. To make the point, angular momentum is what keeps gyroscopes spinning in place and X-zyLo flying straight and stably through the air. The force that it creates is called **centrifugal force**. It resists any other force that tries to change the gravity, wind, a collision with another object, etc.

Let's try another experiment.

Fill a bucket with water. Hold it to your side and then start swinging it back and forth and once you get the bucket swinging fast enough, swing it all the way around so that it makes an entire loop. Why didn't the water fall out when the bucket was upside down? It is because angular momentum created a centrifugal force that held it in. Although there is not an actual "force" that keeps the water in, the water wants to travel in a straight line but the bucket is spinning, so the water stays in.



## 8. Gyroscopic Precession

You have observed that X-zyLo curves left at the end of its flight. This is because its spinning momentum slowed which caused the strength of its centrifugal force to weaken. When this happens gravity pulls the nose of X-zyLo down and it moves to the left in a direction opposite to its spin. Now throw the X-zyLo with it spinning the opposite way (either have a left-hander throw it or throw it under hand). Does it curve? Does it curve the same way at the end, or does it curve the other way? The curving of X-zyLo at the end of its flight demonstrates **gyroscopic precession**.

Gyroscopic precession states that a spinning body tends to react to a disturbing force by rotating in a direction at right angles to the direction of the torque. The equation for gyroscopic precession is  $P=T/H$  where P is the rate of precession, T is the applied torque and H is the angular momentum.

## 9. What Makes X-zyLo Fly?

You have seen that:

- A. Planes fly because of their aerodynamic characteristics.
- B. Gyroscopes resist gravity and stand straight up because they efficiently spin.

The technology that enables the spectacular flight performance of X-zyLo utilizes both aerodynamic and gyroscopic phenomena. The top and bottom of the cylinder give X-zyLo lift similar to that of a bi-winged plane and the rapid spinning of the heavy ring gives it stability and prevents it from nosing down to the ground. However, it is unclear exactly how the two interact. The interactions are very complex and there are different and conflicting theories as to what goes on.

How does X-zyLo fly straight when the principle of gyroscopic precession states that rapidly spinning bodies should turn right angles when outside forces, such as gravity, are applied against them? Some observers say that certain aerodynamic forces affect the right angle turning tendency of gyroscopic characteristics. Others are not so sure. What do you think?

### Pictures of X-zyLo









You can buy an X-zyLo online right now at [www.hiflykites.co.za](http://www.hiflykites.co.za). See you there!

