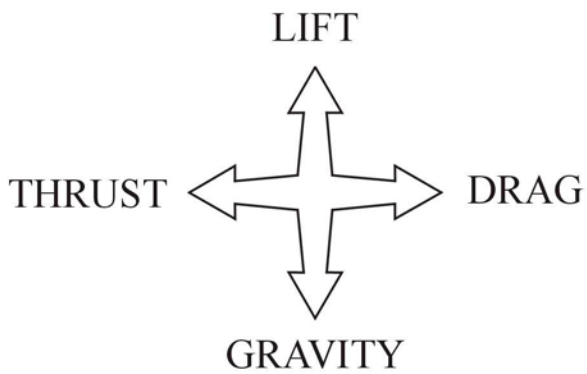

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AERODYNAMICS

is all about

CREATING CHANGES IN AIR PRESSURE

To create **LIFT** (or a positive upward force to counter the pull of **GRAVITY**), the wing must move air molecules out of their normal at rest position. The wing will need to be slightly tilted upward at the leading edge. This is called a positive angle of attack. As a wing passes through the air it is dividing a massive sea of molecules. The leading edge of the wing is the dividing point. What happens to these molecules that are disturbed as the wing passes through them will have an effect on the wing.

If air molecules are pushed together their collective air pressure will be greater. If they are spread apart, their air pressure will be lowered. Higher pressure under the wing and lower pressure above it will cause the wing to be lifted toward the lower pressure side, and will tend to lift upward.

The molecules that pass below the wing are pushed downward toward the rest of the sea of molecules below it. To a very slight extent, this packs the molecules a little closer together which is another way of saying that it slightly increases the air pressure just below the wing. Because air (made up of billions and billions of molecules) is very springy, the actual higher pressure created is very, very slight. What is even more significant is what is happening on the top of the wing.

Since the wing is slightly tilted with the leading edge higher than the trailing edge (a positive angle of attack), the molecules that are just above the wing will have to rush downward to fill the void that would have been created above it as it moves forward. These molecules are being spread apart as they rush downward away from the other molecules at rest above them. Since molecules that are spread apart have a lower pressure than molecules that are packed together, there is a lower pressure area established above the wing. This makes the relatively higher pressure air under the wing push it toward the lower pressure air above it. This is **LIFT** and can be used to overcome **GRAVITY** that is trying to pull the airplane downward.

The faster the wing moves forward, the more air molecules it moves through. This will cause a greater change in the air pressure both above and below the wing. The greater this difference in pressure is, the greater the **LIFT** will be.

However, to move these air molecules out of their normal at rest position takes energy. We could relate this energy to **DRAG**. The way that the air molecules are made to move out of their normal position will affect the efficiency of the wing and the overall **DRAG** of the wing. Newton's First Law of Physics states that a body at rest will remain at rest until acted upon by an external force. Even these little air molecules follow this rule. Our wing will force them out of their position. The quicker and the further that we make them move, the more energy that it takes. The highest performance results in disturbing the air molecules the minimum amount necessary to get the desired results. Or in aerodynamic terms, we try to minimize the **DRAG**. Changing the shape or the angle that a wing penetrates through the air will change the position of the air molecules around it, creating higher or lower pressure areas.

If the wing is tilted even higher at the front edge than before (and the airplane continues going forward in the same direction and at the same speed), it will displace more air molecules causing higher high pressure under the wing and lower low pressure above it. This will create greater **LIFT** and allow the airplane to be heavier to go in the same path. However, it will have greater **DRAG** because it is displacing more air molecules and making them move further, which takes more energy. So our goal is to keep the wing at as small an angle possible to obtain just the minimum **LIFT** that will be necessary to fly our airplane and minimize the **DRAG** and the **THRUST** requirement. The heavier the plane is, the more **LIFT** that it needs and therefore the higher **DRAG** that it will have and will also require more **THRUST** to propel it at the speed necessary to keep it flying. The lighter your plane, the less **LIFT** it needs to battle **GRAVITY**, and the less **THRUST** it needs to battle the decreased **DRAG**. **A light airplane will make it easiest to win competitions!**

The **ANGLE OF ATTACK** is the angle of the wing in relation to the air that it is penetrating through (in our case its flight path). The key to making this airplane fly maximum duration is to force it to fly on both wings, the primary wing up front and the secondary wing in the back (Horizontal Stabilizer). By forcing the tail to carry a portion of the airplane's weight it decreases the amount of weight that the wing has to carry. Wings obtain lift when angled slightly upward at the wing's leading edge. This is called a **POSITIVE Angle of Attack**. This angle combined with the speed of flight determines the lift. **The greater the Angle of Attack the greater the Drag**. This angle changes throughout the course of the flight. Our goal is to balance the Angle of Attack and the speed of the flight in such a way that we minimize drag and therefore reduce the power necessary to keep our plane aloft. With less power necessary, the rubber motor can be thinner (and therefore longer at 2 gr.) and allow the propeller to turn longer. There are a number of factors that will influence this important Angle of Attack, especially the model's weight and the Center of Gravity.

The propeller is nothing more than a rotary wing. Instead of going in a straight line, the blades (each one is a wing) go around in a circular path. As described in the wing paragraph, these blades are pushed through air molecules (in this case we are using the stored energy in our wound up rubber band to turn the propeller). The molecules that go under the rear face are pushed backward and are packed just a little bit closer together than they were at rest creating a tiny bit higher pressure. The molecules going over the top will be sucked toward the forward surface of the propeller blade causing them to spread apart from the other molecules beyond them, creating a lower pressure area. Therefore, the propeller is pulled forward, toward the lower pressure. This is EXACTLY the same as with the wing that is traveling in a straight line. The wing had to be tilted slightly higher at the leading edge to create **LIFT**, as does the propeller. Each blade needs to needs to be tilted to a **Positive Angle of Attack** to create **THRUST**. In propeller terminology this angle is called the **Pitch**. **THRUST** is just **LIFT** turned roughly 90 degrees to point it forward. The more angled the blades are (at a given speed), the greater the pressure difference will be between the front of the blade (lower pressure) and the back (higher pressure). The problem is that it will now take more force to keep the propeller turning the same speed. This means that we would need a thicker, stronger rubber band.

There is another way of increasing **THRUST** (or horizontal lift). If the propeller blades are twisted to a lower pitch (not as great an angle), they will not displace as many air molecules each time they go around. This means that they will have lower **DRAG** as well as lower **LIFT** *for each revolution*. But the propeller now will turn faster (with the same force from the rubber motor) and maybe go through even *more* total air molecules per given period of time. This would mean that you now have greater **THRUST**! The problem is that you are now using up the winds of your rubber motor faster, and may run out before you have flown long enough to win your competition. One solution could be to reduce your rubber size since thinner rubber has less power and will cause the propeller to turn slower, extending the propeller run time. But if the propeller now turns too slowly, it will not develop enough **THRUST** to keep your plane flying at the end of the flight. So this competition is all about balancing the power of the stored energy in the rubber motor with the ability of the propeller to develop enough **THRUST** to fly your airplane for the longest duration.

This brings up the shape of the propeller blade. A cambered surface is an efficient low speed airfoil. This curved shape more gradually accelerates the air molecules into their new positions (both pushing them together for higher pressure and spreading them apart for lower pressure). As mentioned before, the **Pitch** ***is the angle of the blade***. But for the highest efficiency, ***the pitch should gradually change*** from the **Root** (near the center) to the **Tip**. As the propeller turns, ***the outside edge*** (the tip) ***goes the greatest distance*** because it is traveling around the greatest circumference. As you progress toward the center of the propeller it will be traveling a shorter distance for every revolution because it will move a shorter distance (smaller circumference). Therefore, to move an equivalent amount of air for each revolution, the ***pitch (angle) should be greater near the center and less near the tip***. Most commercially available propellers are designed that way to increase their efficiency. This constantly changing pitch across the length of the blade is called a helical pitch. There is a simple means of accomplishing this type of helical pitch with a simple cylindrically cambered piece of plastic. ***By tilting the axis of the blade cut*** about 15 degrees (tip forward) to the axis of the cambered plastic sheet, ***you will yield a coarser pitch (more angled) at the center and a flatter pitch (less angled) at the tip***. This is what you want for greater efficiency. Slightly changing the angle of this axis will affect a change in pitch from root to tip.

There is also a bit of an art in experimenting with the outline of the blade. Most aerodynamicists will agree that an elliptical shaped tip (smooth rounded with a varying radius) is the most efficient, as it minimizes unnecessarily swirling air molecules around the tip because of the higher pressure air being sucked toward the lower pressure air. This is something that will occur with a square cut tip. However, the faster moving outer portion of the blade is where some of the most valuable lift (thrust) is created. Especially with smaller diameter propellers, it may be necessary to utilize a wider airfoil all the way to the tip to create the desired thrust. This would mean keeping a square cut or at least a very blunt tip. The highest efficiency wings are long and thin. This would be my choice with our propellers too, except that the rules regulate the maximum length of the propeller (keeping them ***much shorter than optimum***).

The width of each blade is another area to experiment. A wider blade (with a given camber) will displace more air with each revolution but could be set to a lesser pitch. Generally this approach would favor a thicker rubber band. A narrower blade could displace less air with each revolution and therefore have less drag, but it would turn faster and could use a thinner rubber band that could hold more winds. Not only are these generalities food for thought, but the width that you choose could also be applied gradually across the length of the blade. Maybe designing your blade to be wider in the middle then gradually thinning toward to tip would be good? Maybe very wide all of the way to the root? Maybe a svelte high aspect ratio (sleek and slim) using a very thin rubber motor? You decide. Look at all of the propellers that you can find to see if you can figure out what might work best for your plane.

Experimentation will rule! More than ever, this year you can control your destiny in this event!