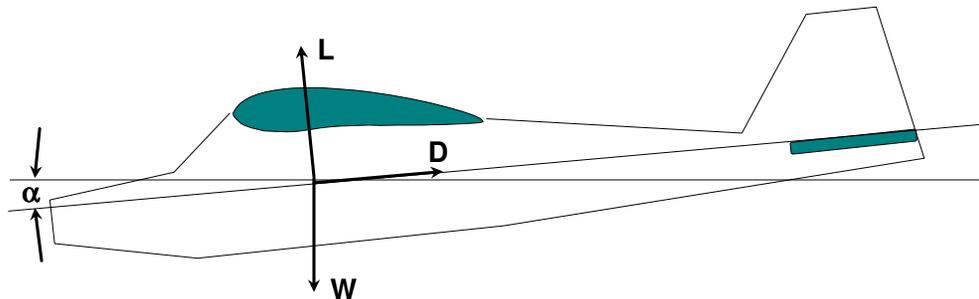


MESA Glider/Airplane Design

Glider Basic Physics:

1. Force available to get to maximum height is fixed, and not large
(1 #32 rubber band).
Therefore minimize weight and drag.
2. Forces acting on model in flight are lift (L), drag (D), and weight (W).



If α = angle of descent,

$$L = W \cos \alpha$$

$$D = W \sin \alpha$$

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Basic Physics (contd.)

Lift and drag are proportional to wing area (S), and speed squared (V^2)

$$L = \frac{1}{2} \rho C_L S V^2 \text{ and}$$

$$D = \frac{1}{2} \rho C_D S V^2$$

Where ρ = air density,

C_L = lift coefficient (function of wing airfoil section), and

C_D = drag coefficient (function of airplane smoothness and lift).

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We have two slightly different problems. For middle schools we are looking for maximum distance, and for 9th and 10th grades, maximum time aloft.

The distance traveled from a given height is given by

$$d = h / \tan \alpha = h \cdot L / D = h \cdot C_L / C_D$$

So we want a glider with a good wing design and low drag. As noted earlier, the higher the starting point for the glide, the longer the distance traveled, which means we want light weight.

For maximum time aloft, we still need to get as high as possible initially, but the time (t) to descend from a fixed height (h) is given by

$$t = h / V \tan \alpha = h \cdot (L / D) / V$$

$$\text{where } V = (2 L / \rho C_L S)^{1/2}$$

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If α is small, the lift L approximately equals the weight W , and so

$$\begin{aligned} t &= h (C_L / C_D) (\rho C_L S / 2 W)^{1/2} \\ &= h (\rho / 2)^{1/2} (S / W)^{1/2} (C_L^{3/2} / C_D) \end{aligned}$$

So we want to maximize the height, maximize the ratio $(C_L^{3/2} / C_D)$, & minimize the wing loading (W/S) , weight divided by wing area.

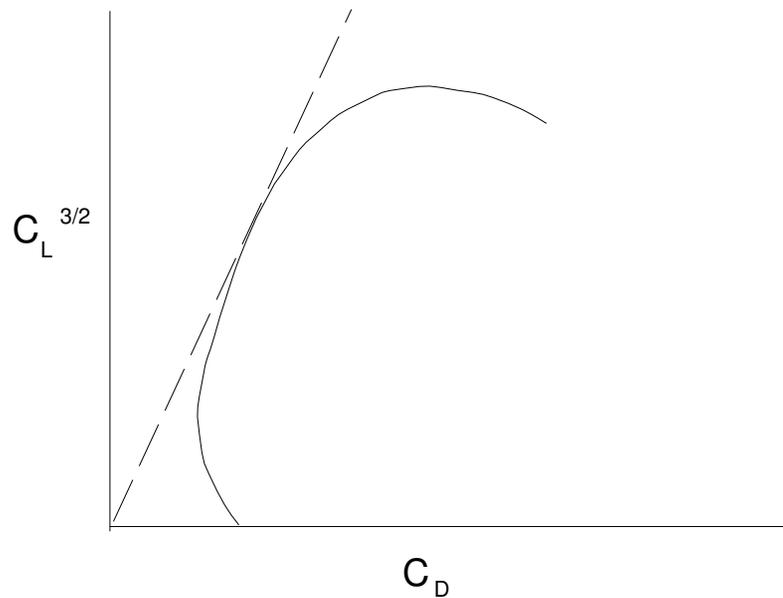
Note that, as we want to keep the weight down to get maximum height for both competitions, the only significant design difference between going for distance versus time is the optimization of (C_L / C_D) versus $(C_L^{3/2} / C_D)$.

We'll discuss $(C_L^{3/2} / C_D)$ as an example. The only difference will be that the shape of the curve for (C_L / C_D) is not quite the same. The important thing is how we trim our glider to get the best performance.

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How do we maximize $(C_L^{3/2} / C_D)$?

A typical wing airfoil section might have a $C_L^{3/2} / C_D$ curve that looks like this, with the maximum value given by the tangent, as shown.



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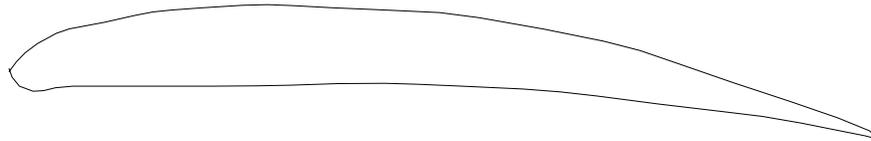
At the bottom of the curve, the wing is generating no lift, and will be at a slightly negative angle to the airstream. We call this angle the angle of attack. As we increase the angle of attack, the lift increases and the drag reduces. With further increase of lift, the drag also starts to rise. Eventually the wing reaches its maximum value of lift, perhaps at about 18 degrees angle of attack, and the wing stalls. The drag increases very rapidly as the lift starts to fall off from the stalled wing. Stall is the point where the airflow breaks away from the wing.

The tangent to the curve represents the point where the ratio of $(C_L^{3/2} / C_D)$ is greatest, and is fairly close to the value for maximum lift. So we want to trim our glider to fly fairly close to stalling. The (C_L / C_D) curve is similar, but we will reach our maximum value at a lower angle of attack. Now let's look at how we design the gliders to maximize their performance.

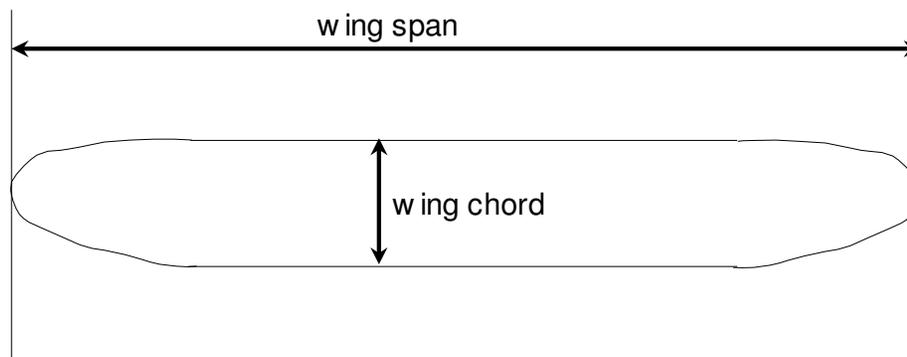
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We are concerned with two general areas, performance and stability.

For long time in the air, we want a high $C_L^{3/2} / C_D$ ratio. This generally means a cambered wing section, something like this.



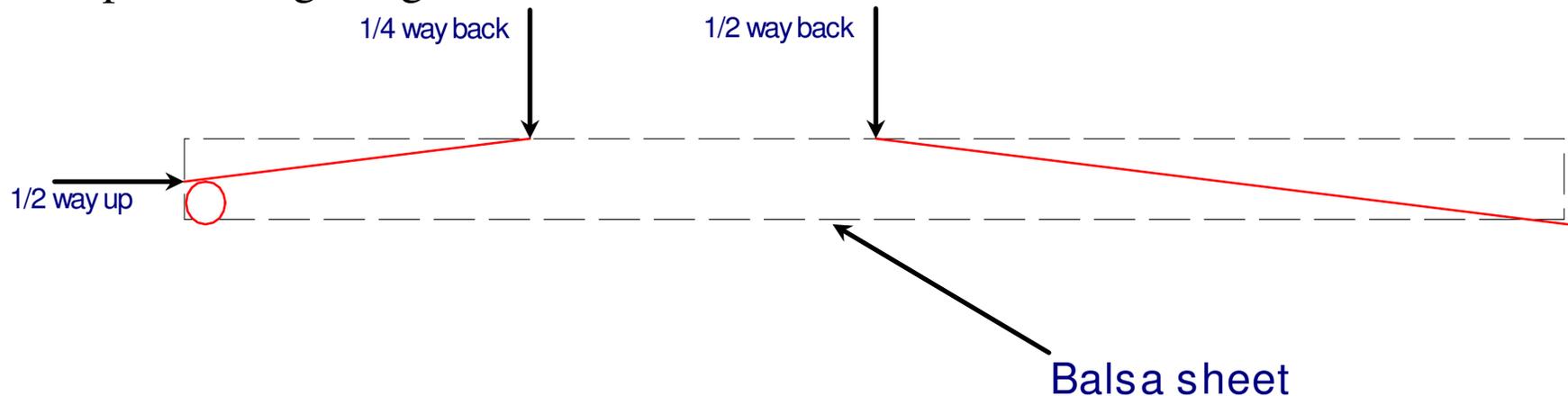
For long distance, we can do with less camber and therefore less drag. In both cases we want a fairly high ratio of wing span to wing chord.



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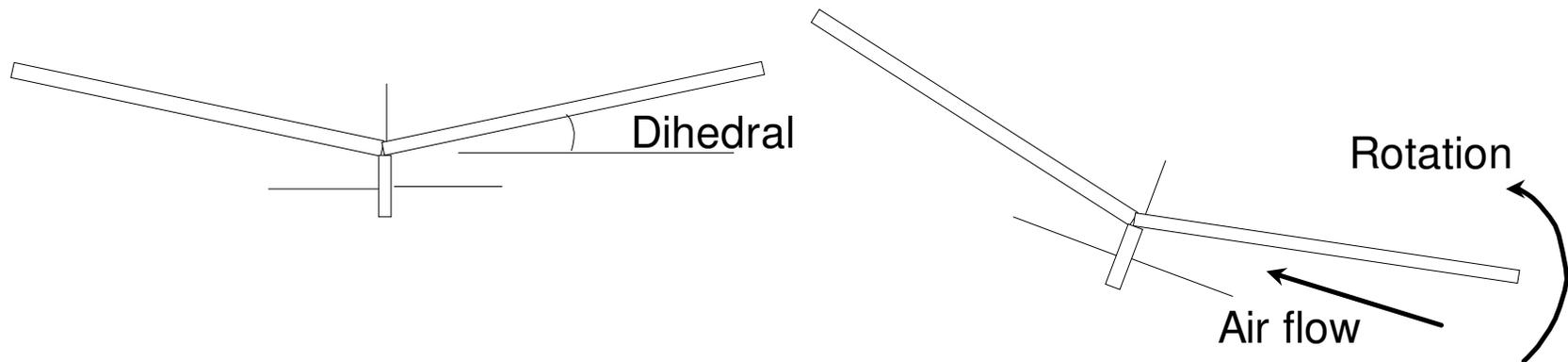
Here's a fairly good starting point for a glider wing section that will work quite well for both types of competition.

Cut a sheet of 1/16" to 3/16" balsa to the plan view of your glider, and draw a couple of lines on it, 1/4 way back from the leading edge, and 1/2 way back from the leading edge. Then draw another line splitting the leading edge as shown below. Sand in straight lines to give a rough airfoil shape as shown, round off the leading edge and the two ridges on top, and you've got a reasonably simple, well-performing wing.



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For stability, we need vertical and horizontal tail feathers, just like an arrow or a dart. We also need some dihedral on the wing, so that if it slips sideways, it will naturally come back to a horizontal position.



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To optimize (C_L / C_D) or $(C_L^{3/2} / C_D)$, we adjust the center of gravity.

With the wing and horizontal tail both at the same angle to the body (the wing could be a degree or two more, but never less than the tail), put modeling clay on the nose so that it balances about 25% back from the leading edge of the wing.

Throw it smoothly or use the catapult not fully stretched to have the glider go straight ahead without climbing. Remove clay a little at a time until it glides the longest distance (i.e. best C_L / C_D). This will be what is required for the distance competition. Then remove a bit more, until it flies, perhaps with a very slight undulation, to give the longest time (i.e. best $C_L^{3/2} / C_D$).

Put it on the catapult, inclined upwards to reach the maximum height, and rolled to one side to ensure that it will fly in a circle for the timed competition – and win the contest!

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Now for the propeller-driven airplane competition.

Not surprisingly, the principles are unchanged from those for the gliders. The major differences are that the rules allow built-up structures, and so our wing section can be a bit more sophisticated. We are no longer constrained to a solid balsa sheet wing, and so can come up with a more efficient airfoil section. Again, as for the gliders, our power source is fixed by the particular propeller we can use, and the rubber band motor. So it remains to the student to make the airplane strong enough to withstand the tension forces from the rubber motor, but still light enough to achieve a reasonable height under power before gliding back to the ground. As the physical principles are not different, they will not be repeated here. Follow similar rules to those given for the gliders and go off and win the contest!