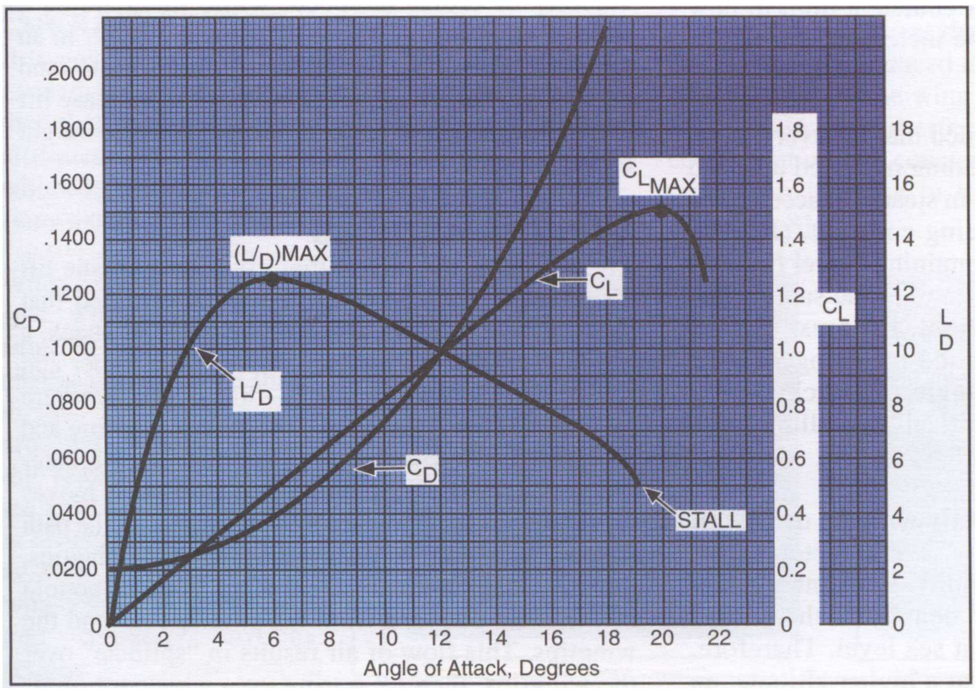
# Lift and Drag curves for the Wing

**INTRODUCTION** The chart below is typical for the wing section for general aviation aircraft. It depicts the coefficients of Lift and Drag against Angle of Attack. There are three curves on this chart. The curve labeled $\mathbf{C_L}$ is the lift coefficient. The curve labeled $\mathbf{C_D}$ is the drag coefficient.




The third curve is the ratio of lift coefficient to the drag coefficient. This curve is labeled L/D.

The coefficients $\mathbf{C_L}$ and $\mathbf{C_D}$ are simply dimensionless numbers that when multiplied by the square of the velocity, the density of air and the wing area give the result in Lift or Drag in Pounds of Force.

**LIFT COEFFICIENT** Notice that at zero angle of attack no lift is being produced, only drag, and the coefficient of Drag, $\mathbf{C_D}$, is at the lowest possible value. To illustrate what these curves mean we can use the example of a Cessna 172 flying at 110 kts with the power set to 2400 RPM and at a weight of 2500 lbs. From experience (looking out the window) you might estimate that the Angle of attack is pretty flat for an estimate lets' say $4^{o}$. You can estimate from the chart above that the value for $\mathbf{C_L}$ to be 0.3. So the simplified formula for determining the Lift would be:

**Lift = K * $110^2$ * 0.3** Where K is all the constants which are not relevant to understanding the fundamentals of these curves. We do know that the lift must equal the weight, so it must be 2500 lbs.

**K = 2500 / ($110^2$ * 0.3 )**
**K= .689**

The next step to understanding how these curves relate to the real airplane is to see what happens to the Angle of Attack if we slow the airplane to 55 kts. We calculated K which is just a constant value made up of the air density and the wing area. At 55 kts and the same weight we can calculate the new $\mathbf{C_L}$.

$$2500 = .689 * 55^2 * X$$
$$X = 2500 / (.689 * 3025)$$
$$X = 1.19$$

Looking at the chart you can find the Angle of Attack that will produce a $C_L$ of 1.19. That corresponds to an angle of 15°. Which you know from experience is very close to where the airplane will stall and pretty much what it looks like in slow flight.

**MANEUVERING SPEED** This is a good time to introduce *Maneuvering Speed*, or **Va** as it is referred to. This is the speed at which you can abruptly pull back on the controls, or fly into a sharp upward gust and stall the wing before overloading it. Looking at the $C_L$ curve you can see that at our example of flying at 110 kts, and at the given weight we, only have a coefficient of lift of 0.3. Sharply pulling back on the stick can run the angle of attack up to 15 degrees increasing the lift by 4 times at that moment. Sure the airplane will slow down – providing the wings are still attached.

But if we are very heavy airplane will have to be at a higher Angle of Attack – for example 8°. In this condition you have a $C_L$ of 0.6 so pulling back sharply by the same amount can only increase the load on the wings by a factor of 2.

For this reason the *Maneuvering Speed*, or **Va** is given for light and heavy weights. The **Va** for light flight weight will always be lower than for the same aircraft at a heavier weight.

**DRAG COEFFICIENT** Drag has to be balanced by propulsion force for stable flight. The same basic formula and constants apply. To calculate the Drag for the two conditions in the *Lift Discussion* we use the following formula.

$D_{110} = .689 * 110^2 * .024$ Read .024 from the $C_D$ curve at 4° Angle of Attack
$= 200$ **lbs**

And at 55 kts

$D_{55} = .689 * 55^2 * .125$ Read .125 from the $C_D$ curve at 12° Angle of Attack
$= 261$ **lbs**

**L/D CURVE** The ratio of Lift to Drag is a very important parameter for any airplane. In this example the maximum value is at 6° Angle of Attack and has a value of 13. At this point the $C_L$ = 0.5 and the $C_D$ = .04. For our example of the 172 this would be at the following speed.

$$2500 = .689 * V^2 * 0.5$$
$$V^2 = 7257$$
$$V = 85 \text{ kts}$$

At 85 kts the airplane is flying at the most favorable lift for the amount of drag being created. This would be the speed to fly for the maximum range either gliding or under power.

As you increase the aircraft weight you will have to fly faster to remain stable at this angle of attack. So increase the weight and you have to increase the speed and of course carry more power for *Best Range* at the heavier weight.

Understanding the power required for various realms of flight relies on another set of performance curves to be discussed in another paper.

You must also keep in mind this is for the wing only. The rest of the airplane adds drag, and no significant lift. So flight tests are used to generate the numbers in the POH and will always give lower performance numbers that those derived by considering the wing only.