A Different Approach to Teaching Engine-Out Glides

Les Glatt, Ph.D, ATP/CFI-AI, AGI/IGI

When student pilots begin to learn about emergency procedures, the concept of the engine-out glide is introduced. The CFI will usually discuss the procedures to be used when an engine failure has occurred. Typically the discussion goes like this:

(1) When the engine fails, the first step is to establish the aircraft at the airspeed for best glide.
(2) This best glide airspeed allows the aircraft to fly at it maximum L/D ratio, which allows the aircraft to glide the farthest horizontal distance for the least loss in altitude.
(3) The best glide airspeed is given in the POH in the section entitled "Emergency Procedures".
(4) The airspeed that is shown is for the aircraft being loaded to gross weight.
(5) A rule of thumb to obtain the best glide speed at any aircraft weight is to reduce the best glide airspeed at gross weight by one-half the percent reduction in gross weight. Thus, if the aircraft is loaded to 10% below gross weight, you should reduce the best glide speed at gross weight by 5%.

After this discussion with the student, the lesson proceeds with a flight that involves reducing the power to idle and pitching the aircraft to obtain the desired glide airspeed for the weight of the aircraft. The student responds to the simulated engine-out procedure by watching the airspeed indicator and pitches the aircraft to establish the airspeed at the target best glide speed and then trims the aircraft to that speed.

The question we as flight instructors should ask ourselves is "Is this really the proper method of teaching engine-out simulations, or is there a better way?" Fortunately, understanding basic aerodynamics tells us that there is a better way to teach this subject. Here, what I mean by "basic aerodynamics" is the knowledge that is provided in the FAA Handbook of Aeronautical Knowledge (FAA-H-8083-25), chapters 3, 4, and 10. When discussing gliding flight, I usually poll the audience with the following scenario: Two identical aircraft incur an engine failure at 9000 AGL. The first weighs 2400 lbs and the second weighs 2000 lbs. The question I ask is "Which aircraft can glide the farthest before it runs out of altitude? The majority of the answers come back with "the lighter one being able to glide the farthest". The next popular answer is "the heavier one" and the remaining answers are either "both are able to glide the same distance" or "I am not sure". The fact that the correct answer is "they both can glide the same distance", indicates to me that the subject of basic aerodynamics is not properly taught by flight instructors. In fact, in many cases, the flight instructor's answer will also be "the lighter one". In order to shed some light for a different approach to teaching engine-out gliding, we will review the basic aerodynamics of a wings level glide, which will allow the reader to understand why the correct answer is "they both glide the same distance".

Aircraft performance is determined by the balance of forces along and perpendicular to the flight path of the aircraft. Figure 1 shows the aircraft established in a glide. The forces that act on the aircraft during the glide are lift, drag, and weight, with the thrust set to zero. Note that there may be some small amount of thrust at the propeller when the engine is idling, but for this discussion we will assume it is identically zero. Although CFI's are always discussing the concept of angle-of-attack, what is usually missing in the discussion is the concept of what is called flight path angle, which is the direction of the velocity vector of the aircraft in relationship to the local horizontal.

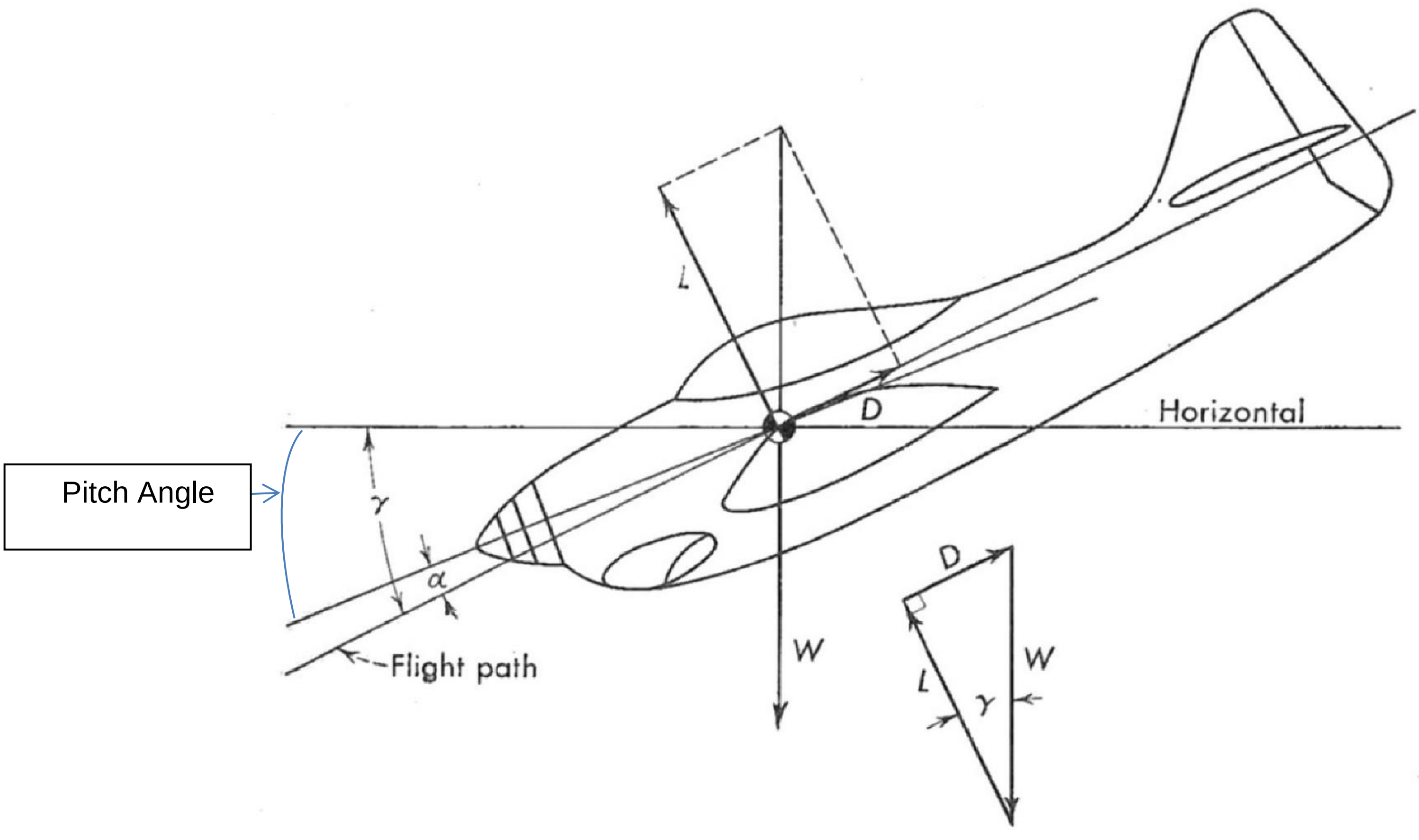

Figure 1: Forces on Aircraft in a Glide

Figure 1 also shows the angle-of attack (α) and the flight path angle (γ). In addition, there is a simple relationship between the flight path angle, the angle-of-attack and the pitch angle of the aircraft. The pitch angle is the angle between the longitudinal axis of the aircraft and the horizontal plane, and is also shown in Figure 1. It is positive when the longitudinal axis is above the horizontal plane and negative below the horizontal plane. If we assume the average wing incidence angle (which is the angle between the chordline of the wing and the longitudinal axis of the aircraft) is zero, a simple relationship exists between the three angles. This relationship is shown below.

Pitch Angle = Flight Path Angle + Angle-of-Attack (1)

The positive sign in equation (1) is required in order to account for the fact that the flight path angle is negative (i.e. below the horizontal) and the angle-of attack is positive (i.e. the chordline is above the velocity vector). Although flight instructors usually emphasize the importance of angle-of-attack, what is interesting is that both the angle-of-attack and flight path angles are angles that are in general not able to be visualized by the pilot in flight. In fact, the only time the pilot can visualize the angle-of-attack in flight, is when the flight path angle is zero, i.e. when the aircraft is in level flight. In this case, the angle-of-attack is equal to the pitch angle as can be seen by the above simple relationship. As an example, when we are performing slow flight at constant altitude, the pitch angle is essentially the angle-of-attack.

Figure 2 shows the same information as Figure 1, except we have decomposed the weight into two components, one along the flight path (W_A) and one perpendicular to the flight path (W_P). The drag force acts in a direction opposite to the velocity of the aircraft. The lift force acts perpendicular to the velocity vector and the weight acts downward. The components of weight along and perpendicular to the flight path can be obtained from simple trigonometric relationships for a right triangle, and are given in equation (2) below:

$$W_A = W Sin\gamma$$

$$W_P = W Cos\gamma \qquad (2)$$

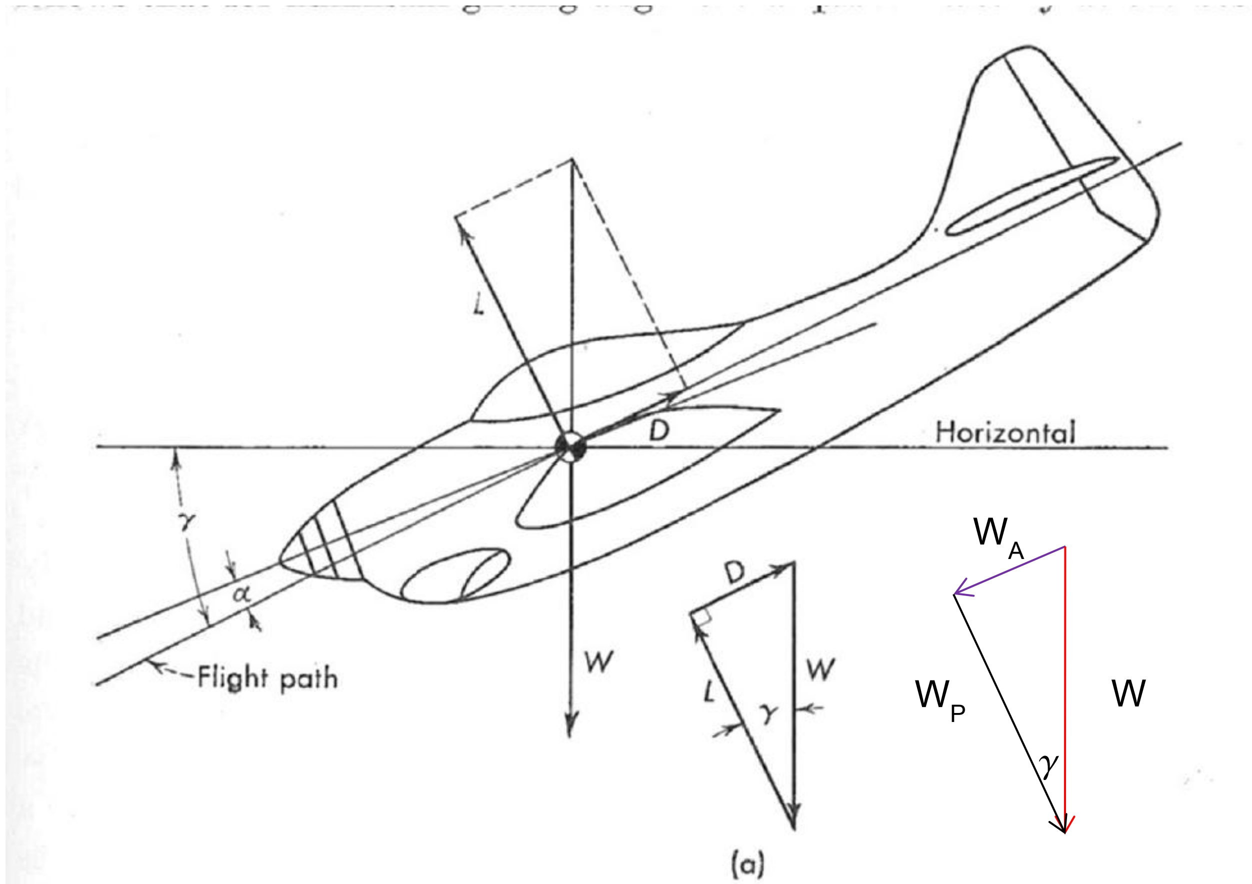

Figure 2: Force on the Aircraft in a Glide

Again, in a steady-state glide, the forces along and perpendicular to the flight path are in balance. Thus, one can write the following relationships for the force balance:

Along the flight path:

$$D = W Sin\gamma \qquad (3)$$

Perpendicular to the flight path:

$$L = W Cos\gamma \qquad (4)$$

Combining these two relationships we find that

$$Tan\gamma = \frac{1}{(L / D)} \qquad (5)$$

This relationship is the most fundamental relationship for gliding flight. It gives us the flight path angle as a function of the lift to drag ratio, i.e., the L/D. In order to minimize the glide path angle, the aircraft needs to fly at a value of L/D which is the maximum the aircraft can attain. This is the reason the flight instructor tells his/her student that we need to fly at the maximum L/D to be able to glide the farthest. However, the above relationship does not provide any information on what the maximum L/D is for the aircraft. In order to obtain information on the L/D ratio, we need to delve a little further into basic aerodynamics.

One can express the lift and drag on the aircraft in the form

$$L = C_L(\frac{1}{2}\rho V^2)\mathrm{S} \qquad (6)$$

$$D = C_D(\frac{1}{2}\rho V^2)\mathrm{S} \qquad (7)$$

Where

C_L = Lift coefficient

C_D = Drag coefficient

ρ = Air density

V = True airspeed

S = Wing area

Therefore,

$$\frac{L}{D} = \frac{C_L}{C_D} \qquad (8)$$

In general one can express the drag coefficient as the sum of the parasite drag (i.e., all drag that is not due to the generation of lift), and the induced drag (i.e., drag that arises out of the generation of lift). This expression is usually given in terms of the lift coefficient. This equation is usually termed the “drag polar” and is of the form

$$C_D = C_{D_0} + kC_L^2 \qquad (9)$$

Where C_{D_0} is the parasite drag coefficient, and kC_L^2 is the induced drag coefficient. Here C_{D_0} and k are constants for the particular aircraft one is flying. One can now express the L/D ratio as

$$\frac{L}{D} = \frac{C_L}{C_{D_0} + kC_L^2} \qquad (10)$$

It can easily be shown that the maximum lift to drag ratio occurs when

$$C_{D_0} = kC_L^2 \qquad (11)$$

The above expression shows that the maximum L/D occurs when the parasite drag is exactly equal to the induced drag. Since C_{D_0} and k are known constants for the aircraft, the L/D can be obtained. However, the L/D can also be obtained from the POH by viewing the “Maximum Glide” chart in the “Emergency Procedures” section. Figure 3 shows a “Maximum Glide” chart” for a C-172. Note that this chart corresponds to a C-172 at gross weight, 65KIAS, propeller windmilling, flaps up and zero wind.

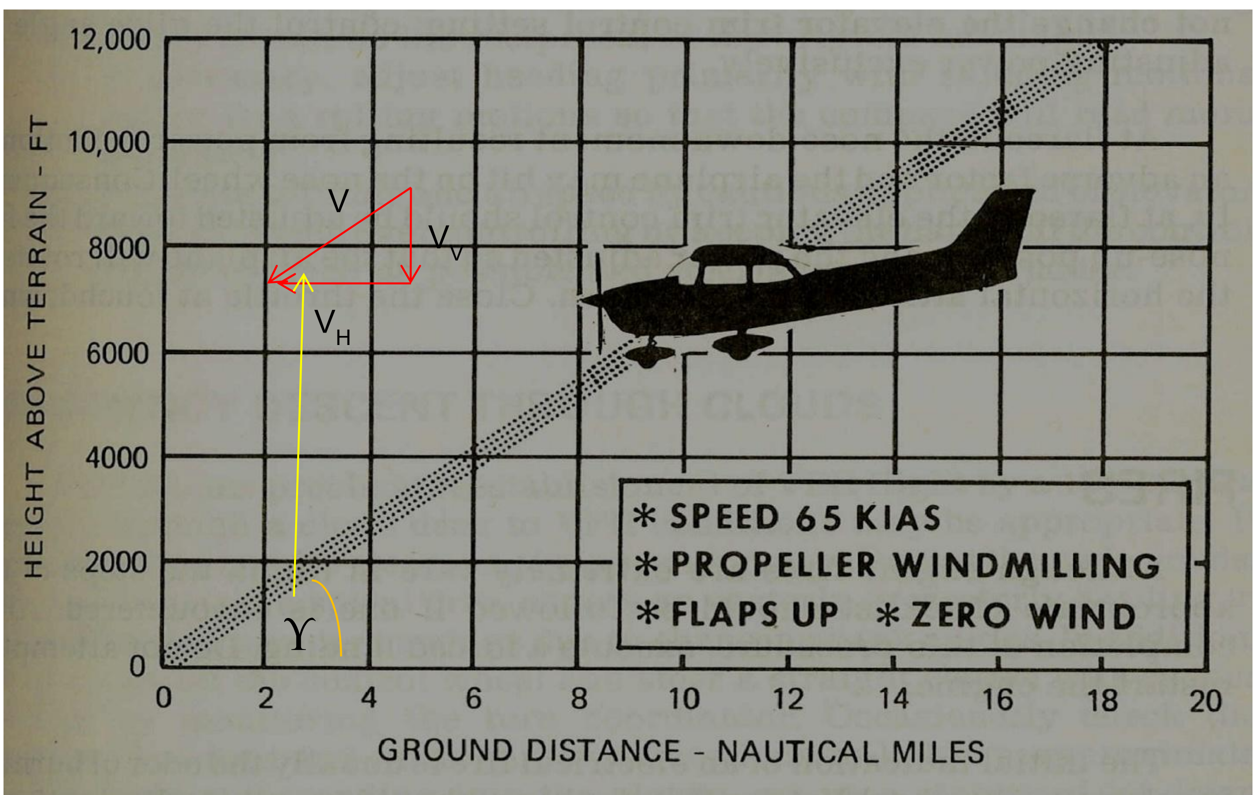

Figure 3-1. Maximum Glide

The L/D ratio can be obtained by dividing the 18 nautical mile distance in feet by the height above the terrain at 18 nautical miles, which is 12000 feet. This ratio is determined to be 9.09. If one substitutes the value of L/D of 9.09 into the glide path equation (5), the flight path angle is determined to be 6.3 degrees below the horizon. This glide path angle is independent of the aircraft altitude or weight of the aircraft. One can easily plot the L/D ratio versus the value of C_L, but it is more informative to plot the L/D as a function of the angle-of attack. The value of C_L of the aircraft is also given as a function of angle-of-attack, so that one can easily plot the L/D versus angle-of-attack. Typical plots of C_L versus angle-of-attack and L/D and C_D versus angle-of-attack are shown in Figure 4. This figure corresponds to a symmetrical airfoil, since the lift is zero at a zero angle-of-attack.

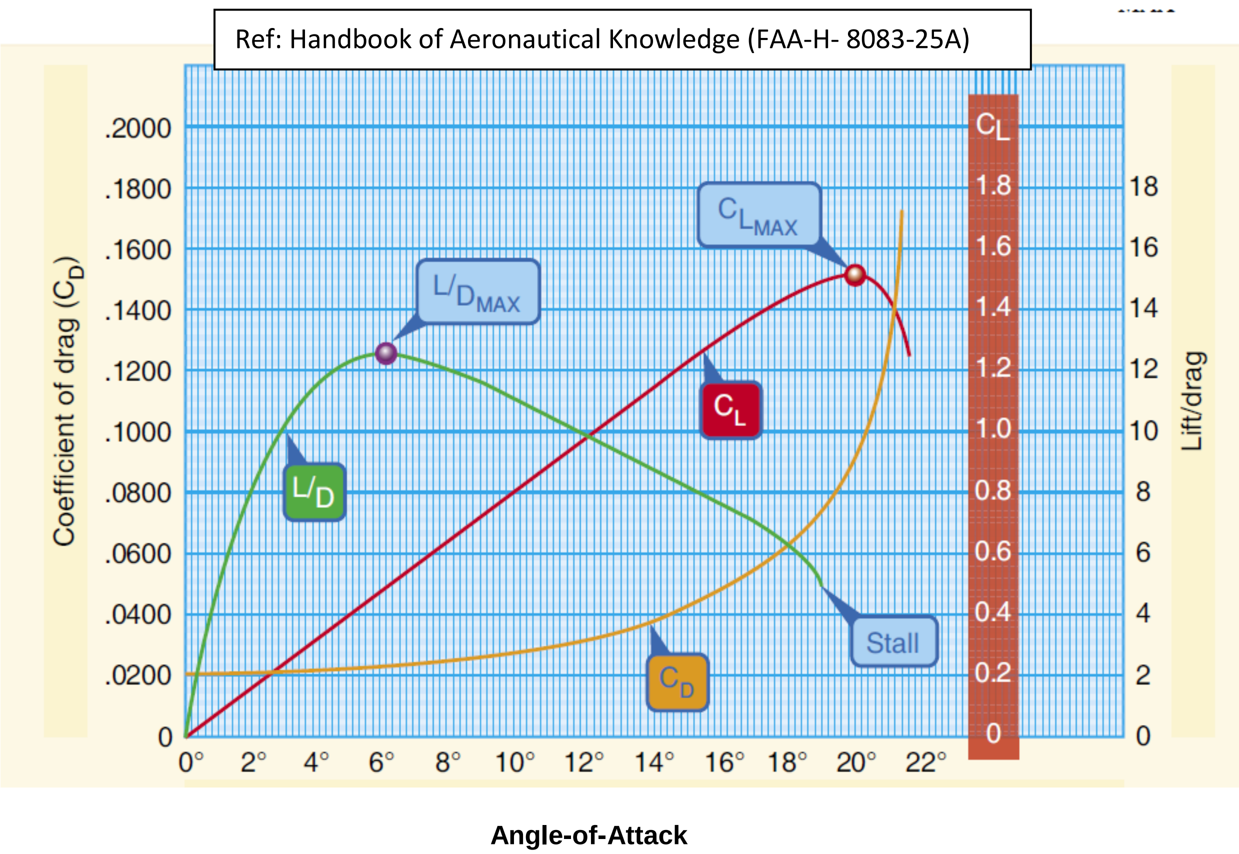

Figure 4: C_L, C_D, and L/D ratio as a function of angle-of-attack

It is clear that the maximum L/D occurs at a fixed angle-of-attack and is independent of both the aircraft weight and the altitude. In addition, the flight path angle is also independent of the aircraft weight and the altitude. In the case of a C-172, the flight path angle was shown to be 6.3 degrees below the horizontal. The maximum L/D for a C-172 occurs somewhere between 6 and 9 degrees angle-of-attack. Using the expression in equation (1), the pitch angle would be somewhere between 0 and 3 degrees above the horizon. Thus, basic aerodynamics tells us that the same pitch attitude should be flown, independent of the weight of the aircraft or the altitude. The exact pitch attitude can be determined either by a plot similar to Figure 4 for a C-172, or one can load the aircraft to gross weight, reduce the power to idle and trim the aircraft to 65KIAS. The pitch attitude for the best glide speed should be noted and that pitch attitude should be used for simulated emergencies, no matter what the weight of the aircraft. Note that in the case of an actual engine failure when the propeller is windmilling, the L/D of the aircraft will be slightly lower than that for the case of the engine at idle. In addition, the lower L/D will occur at a slightly higher angle-of-attack (since the parasite drag coefficient is somewhat higher). Thus, the pitch attitude will be slightly different with the propeller windmilling, as compared to the propeller idling case. Therefore, the standard 5-step briefing on emergency glide procedures will now have a sixth step which will state that the best glide speed for any weight or altitude is attained at a specific pitch attitude.

In summary, we should teach student pilots to establish a given pitch attitude when simulating engine failures, rather than to chase the airspeed, which is going to be dependent of the weight of the aircraft. By establishing the proper pitch attitude at different aircraft weights, the student can observe the resultant airspeeds for the same pitch attitude and thus correlate that with the statement that “the best glide speed is reduced by half the percent reduction in gross weight”. We try to teach our students to maintain visual cues outside the aircraft and setting up a specific pitch attitude for engine-out emergency simulations allows the student to do just that, keep his head out of the cockpit.

For those folks curious about some of the mathematics, I have provided some helpful information in Appendix I.

Any questions or comments should be directed to

Les Glatt

lgtech@roadrunner.com

(818) 414-6890

Appendix I

In regard to the use of trigonometric functions such as the Sine and Cosine of a particular angle, a simple scientific hand calculator can be used to evaluate these functions. However, I have provided the table below which provides this information. Note that a property of the Sines and Cosines is that sum of their squares are equal to 1.

Table of Sines and Cosines

θ (degrees)	Sinθ	Cosθ
0	0	1
30	0.5	0.866
60	0.866	0.5
90	1.0	0
120	0.866	-0.5
150	0.5	-0.866
180	0	-1
210	-0.5	-0.866
240	-0.866	-0.5
270	-1	0
300	-0.866	0.5
330	-0.5	0.866

On page 5, it is stated that the maximum L/D is attained at the angle-of-attack where the parasite drag and induced drag are equal. This conclusion is found by using elementary calculus when trying to locate the maximum of a function. However, it is easy to prove this fact by picking any two values of C_{D_0} and k and plotting the L/D ratio versus the lift coefficient. This can be done using Microsoft Excel. When the maximum is located, you will observe that the parasite drag and the induced drag coefficients are equal. In the case of a C-172 with the propeller windimilling, the value of C_{D_0} is approximately 0.05, and the value of k is approximately 0.06. These values would produce a maximum L/D of 9.09.