Gliding Flight

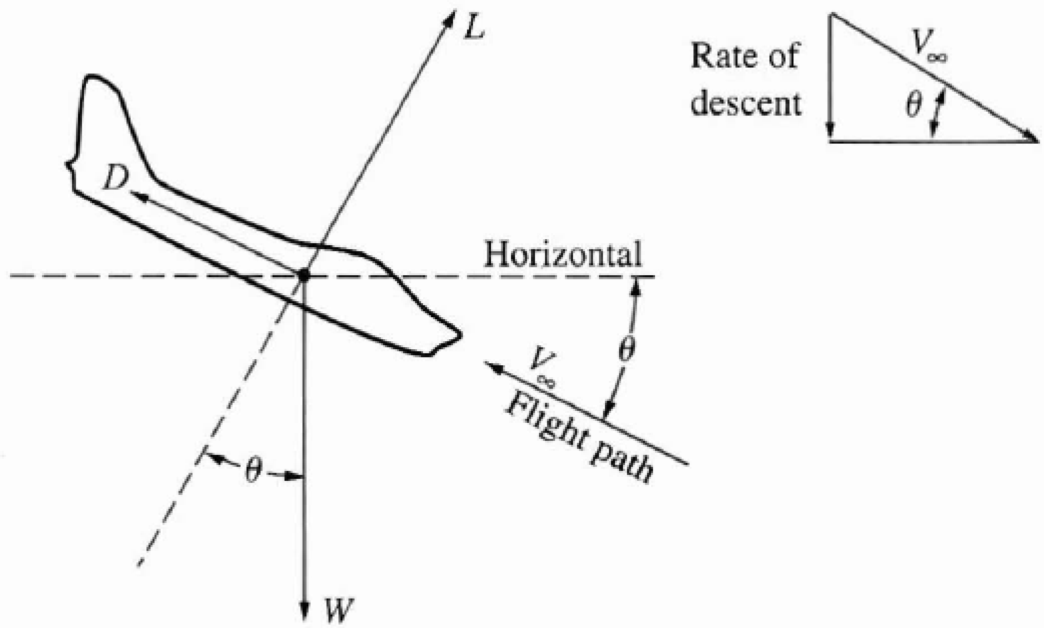
Whenever an airplane is flying such that the power required is ***larger*** than the power available, it will descend rather than climb. In the ultimate situation, there is no power at all; in this case, the airplane will be in gliding. This will occur for a conventional airplane when the engine quits during flight (e.g., engine failure). Also, this is the case for gliders and sailplanes.

The force diagram is

$$L = W\cos\theta$$
$$D = W\sin\theta$$

$$\frac{\sin\theta}{\cos\theta} = \frac{D}{L}$$

$$\text{Tan}\,\theta = \frac{1}{L/D}$$



$$\text{Tan}\,\theta_{\min} = \frac{1}{(L/D)_{\max}}$$

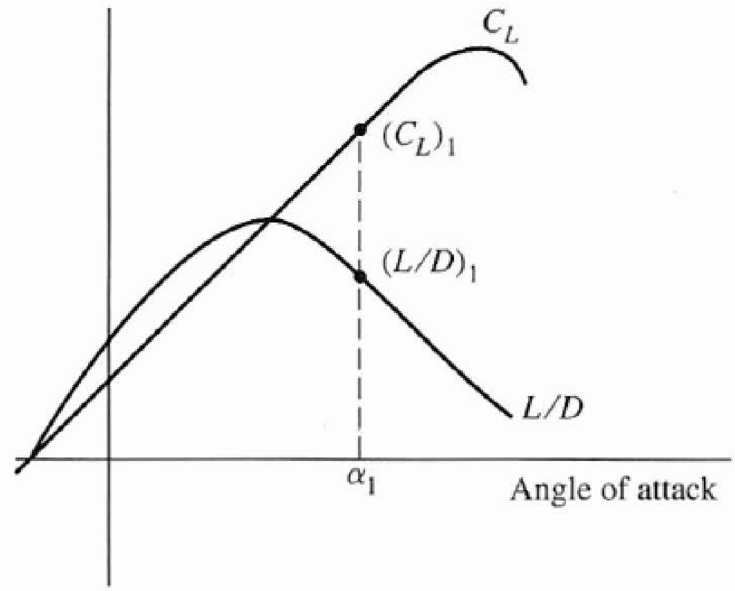
the higher the L/D, the shallower the glide angle. The smallest equilibrium glide angle occurs at (L/D)max.

The equilibrium glide angle does not depend on altitude or wing loading, it simply depends on the lift-to-drag ratio. However, to achieve a given L/D at a given altitude, the aircraft must fly at a specified velocity V, called the *equilibrium glide velocity,* and this value of V, *does* depend on the altitude and wing loading, as follows:

$$\frac{1}{2}\rho_\infty V_\infty^2 S C_L = W\cos\theta$$

$$V_\infty = \sqrt{\frac{2\cos\theta}{\rho_\infty C_L}\frac{W}{S}}$$

it depends on altitude (through rho) and wing loading. The value of CL and L/D are aerodynamic characteristics of the aircraft that vary with angle of attack. A specific value of L/D, corresponds to ***a*** specific angle of attack which in turn dictates the lift coefficient (CL). If L/ D is held constant throughout the glide path, then CL is constant along the glide path. However, the equilibrium velocity along this glide path will change with altitude, decreasing with decreasing altitude (because rho increases).



SERVICE AND ABSOLUTE CEILINGS

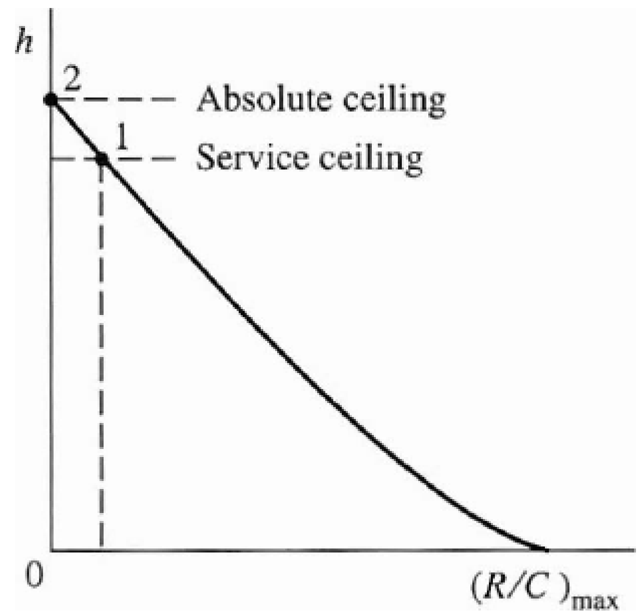
The highest altitude achievable is the altitude where (R/C)max=0. It is defined as the ***absolute ceiling that*** altitude where the maximum rate of climb is zero is in steady, level flight. **A** more useful quantity is the ***service ceiling,*** conventionally defined as that altitude where (R/C)= 100 ft/min. The service ceiling represents the ***practical*** upper limit for steady, level flight. For many conventional airplanes, R/C versus altitude is almost linear. The graphical solution for service and absolute ceilings is straightforward. For a given airplane:

1. Calculate (R/C)max, at a number of different altitudes.

2. Plot the results as in Fig.

3. Extrapolate the curve to a value of (R/C)max = 100 ft/min, denoted by point 1. The corresponding value of h at point 1 is the service ceiling.

1. Extrapolate the curve to a value of (R/C)max = 0, denoted by point 2. The corresponding value of h at point 2 is the service ceiling.

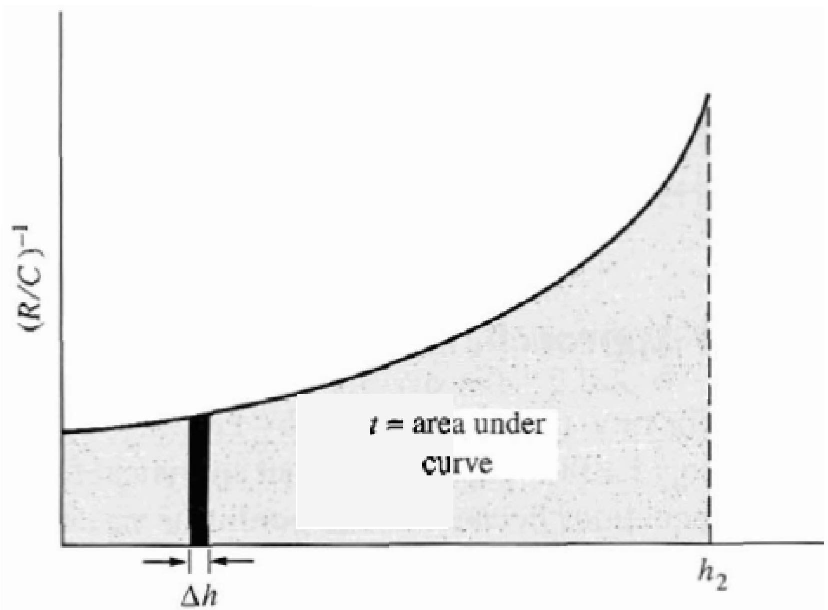


TIME T0 CLIMB

The rate of climb, by definition, is the vertical component of the airplane's velocity, which is simply the time rate of change of altitude *dh/dt.*

$$\frac{dh}{dt} = R/C$$

$$dt = \frac{dh}{R/C} \longrightarrow \boxed{t = \int_0^{h_2} \frac{dh}{R/C}} \longrightarrow \boxed{t_{\min} = \int_0^{h_2} \frac{dh}{(R/C)_{\max}}}$$



Consider a plot of *(R/C)^(-1)* versus altitude. The time to climb to altitude *h2* is simply the area under the curve, shown by the shaded area.

$$t = \int_0^{h_2} \frac{dh}{R/C} \approx \sum_{i=1}^{n} \left(\frac{\Delta h}{R/C}\right)_i$$

$$\left(\frac{\Delta h}{R/C}\right)_1 = \frac{2{,}000}{\frac{1}{2}\left[(R/C)_0 + (R/C)_{2{,}000}\right]}$$

There is no exact analytical formula for *t* that can be obtained from these equations because of the nonlinear variation of rate of climb with altitude. An *approximation is to consider* **(R/C)max** nearly linear with altitude.

$$(R/C)_{\max} = a + bh$$

$$t_{\min} = \int_0^{h_2} \frac{dh}{a + bh} = \frac{1}{b}[\ln(a + bh_2) - \ln a]$$

If you calculate the maximum R/C at two altitudes, you can approximate A line and then calculate a, b and tmin