

ProAdvice 2: THE WING PLANFORM

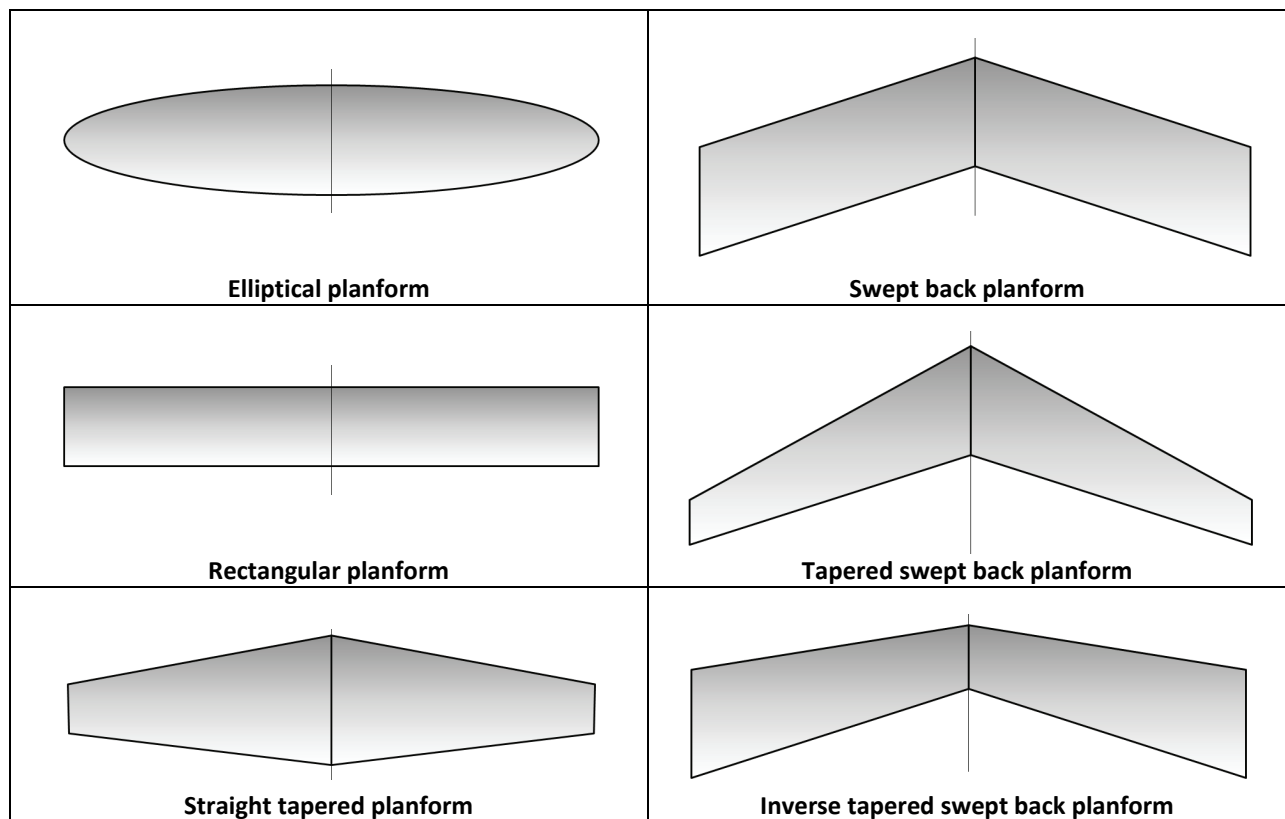
Introduction

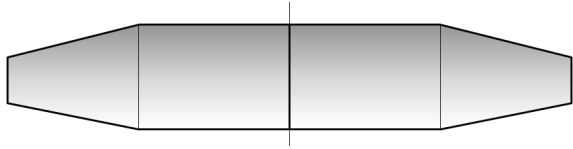
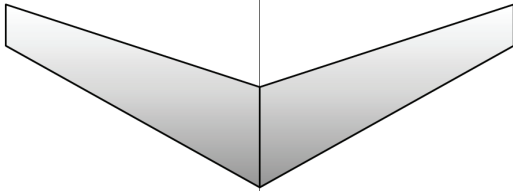
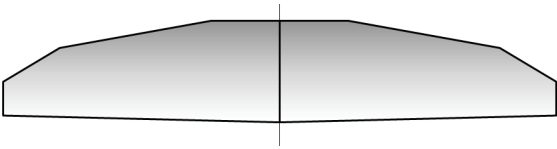
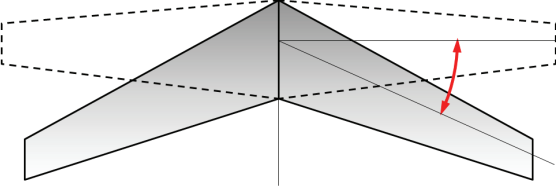
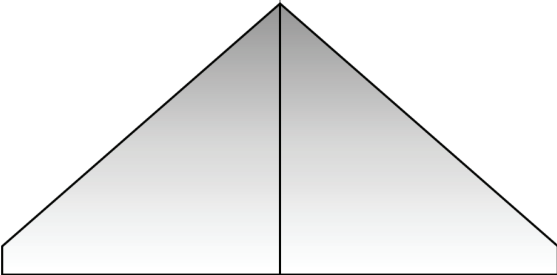
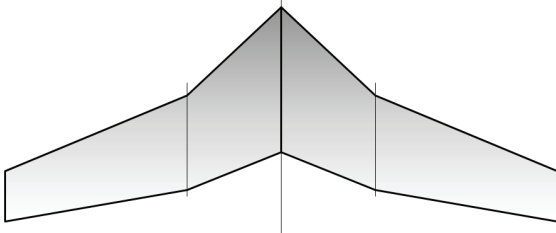
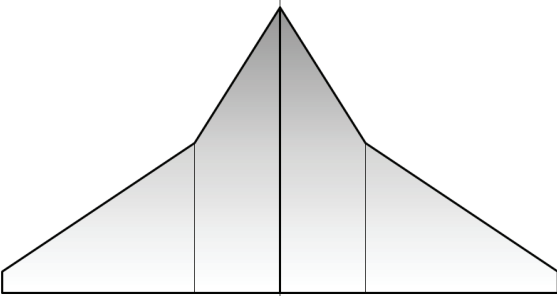
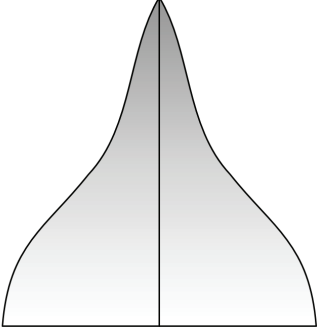
Many areas of the aircraft design process rely on accurate lift estimation. This includes performance analysis, determination of useful load, and structural analysis, to name a few. As an example, any competitive aircraft design requires the useful load to be maximized. This implies the empty weight (which is largely structure and engines) must be minimized. The weight of the airframe can only be reduced if the distribution of pressure loads on the vehicle can be accurately estimated of which the most prominent one is the Lift.

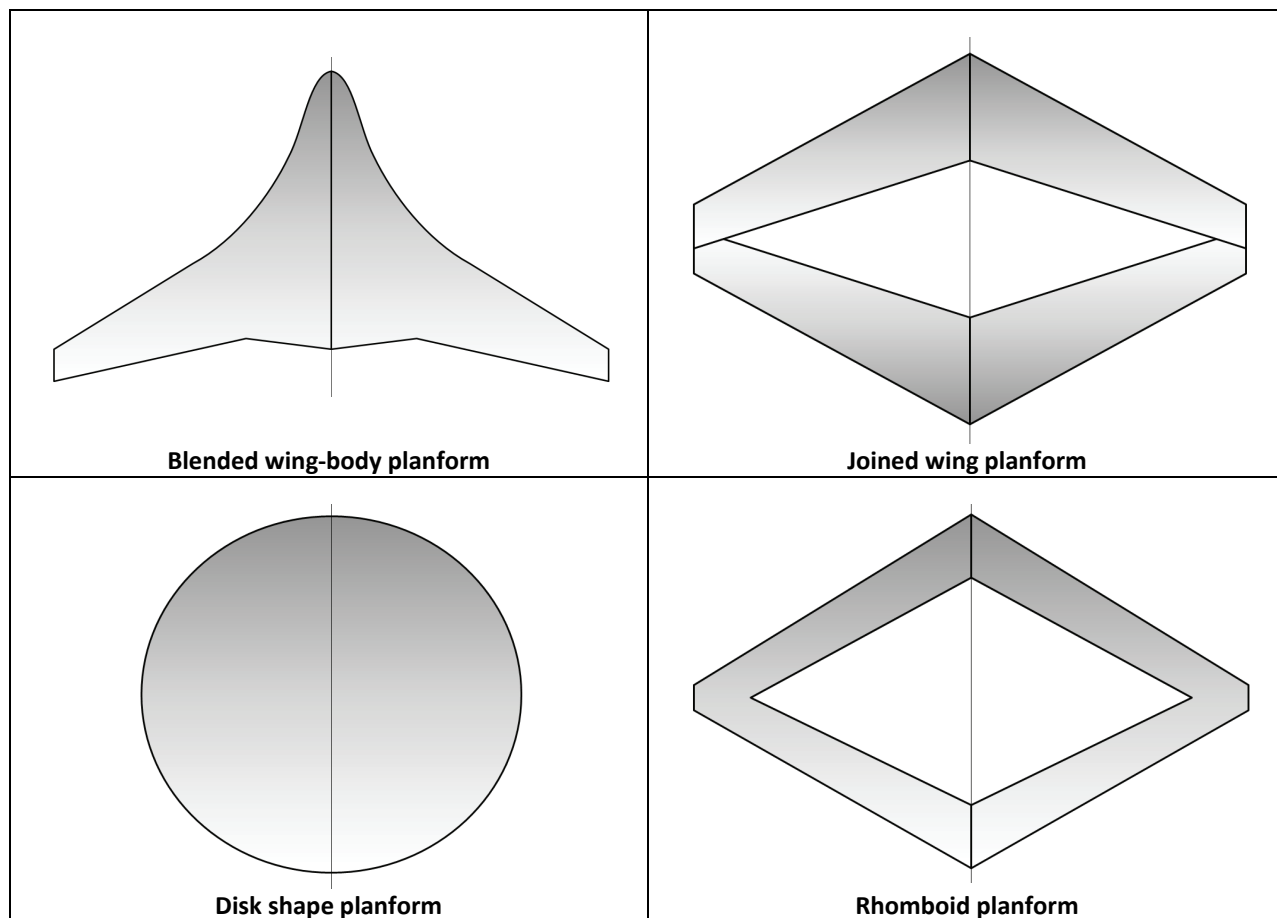
The total force (or resultant force) generated by a wing can be found to depend on several parameters; the wing's geometry, density of air, airspeed, and the angle the chord line of the wing's airfoils make to the flow of air, the Angle-of-Attack (AOA). The wing is a 3D object, but is usually treated as a set of two 2D geometric features; planform (x-y plane) and airfoil (x-z plane).

In this section we will look at one of the two most important design characteristics of lifting surfaces; the wing planform. We will look at a number of wing planforms and evaluate the true lifting capability for some of those using SURFACES. This will give the designer an important insight into the true cost of various planforms and why the designer resorts to a particular section.

Basic Planform Shapes for Lifting Surfaces



 <p>Semi tapered planform</p>	 <p>Tapered forward swept planform</p>
 <p>"Schueman" planform</p>	 <p>Variable sweep planform</p>
 <p>Delta planform</p>	 <p>Crescent planform</p>
 <p>Double-delta planform</p>	 <p>Ogival planform</p>

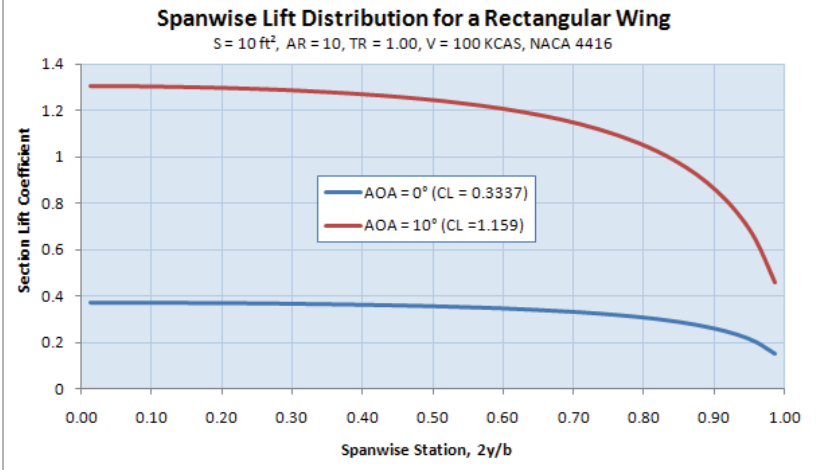
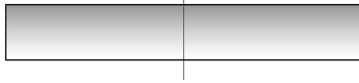


Properties of the Basic Planform Shapes

It is of interest to compare the various planform shapes to a rectangular one at a specific condition. All the planform shapes feature the same reference area (10 ft^2), the same airfoil (NACA 4416) at a constant Angle-of-Attack of 10° and airspeed of 100 KCAS. Wing dihedral and washout is 0° for all examples. Parameters such as Aspect Ratio (AR) and Taper Ratio (TR) are varied to ensure all the examples have an equal area, while featuring values that are representative of actual airplanes. This gives the designer an excellent insight into the impact the planform has on lifting capabilities. For instance, note the lift coefficients these planform shapes achieve at 10° . Examples of aircraft that use the planform is cited as well.

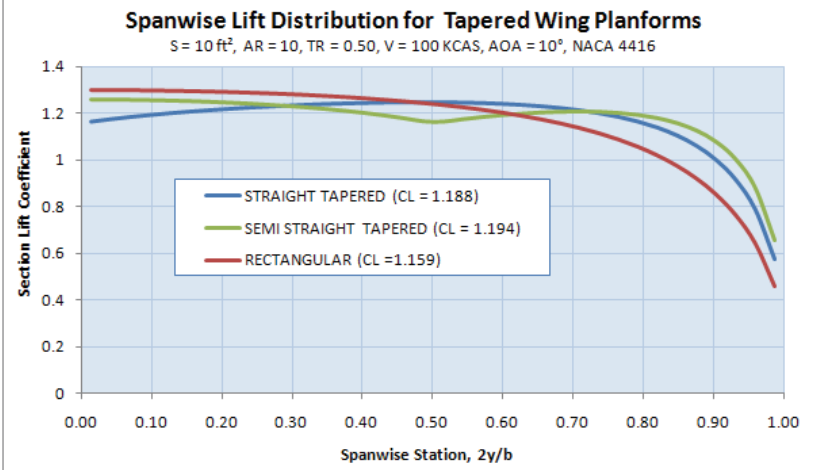
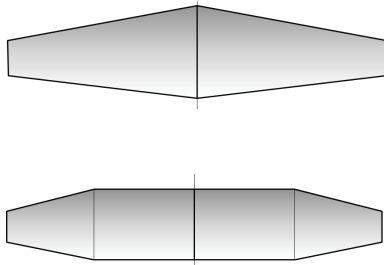
This comparison is implemented via the Vortex-Lattice Method (VLM) SURFACES (available from www.flightlevelengineering.com). All the models have 720 panels.

Rectangular Planform (baseline)



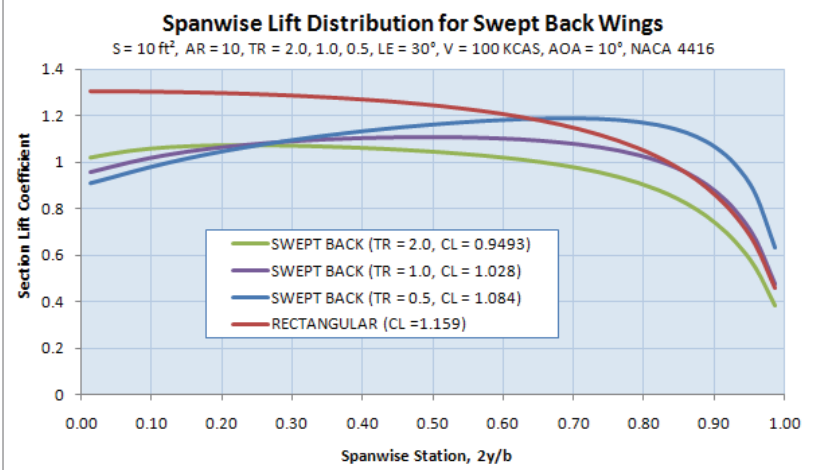
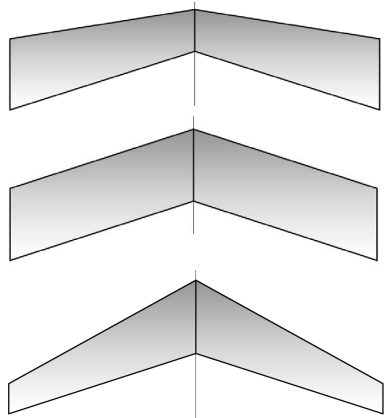
Example of use: Piper PA-38 Tomahawk, Piper PA-28 Cherokee, Piper J-3 Cub

Straight Tapered and Semi-Straight Planform Shapes



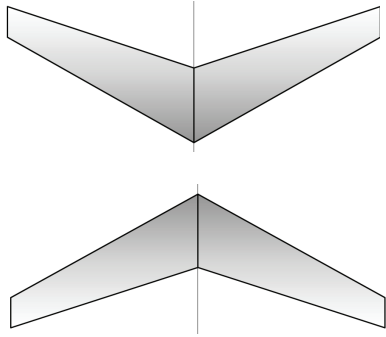
Example of use (straight taper): Cirrus SR20, Cirrus SR22, Cessna 177 Cardinal.
 Example of use (semi taper): Cessna 150/152/172, Piper PA-28 Archer

Swept Back Planform

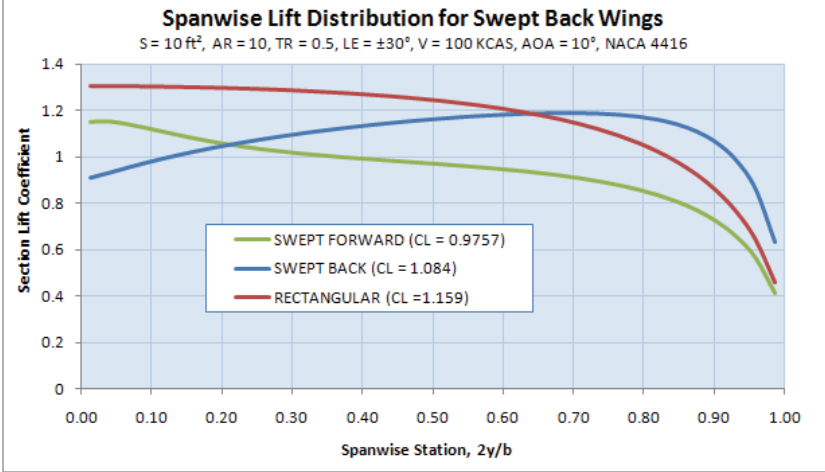


Example of use (TR>1): Republic XF-91 Thunderceptor
 Example of use (TR=1): Boeing B-2 Spirit
 Example of use (TR<1): BAe Hawk T1, Dassault Falcon 10, F-100 Super Sabre, and many, many others.

Swept Forward Planform



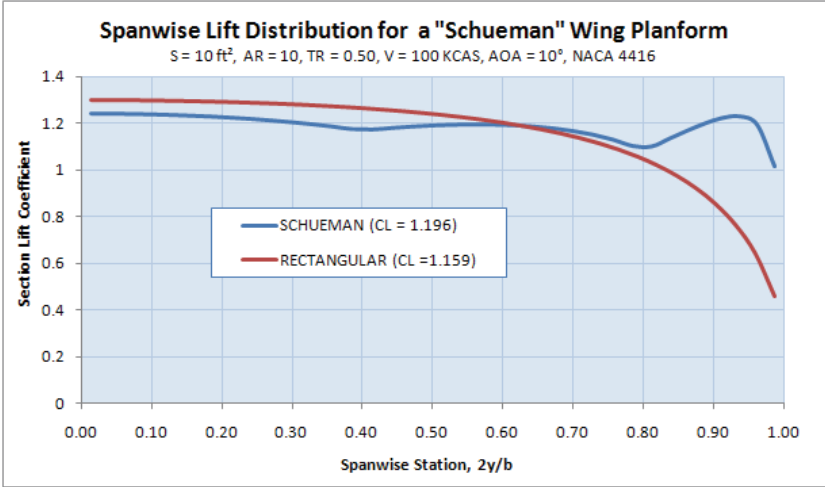
Example of use: Grumman X-29



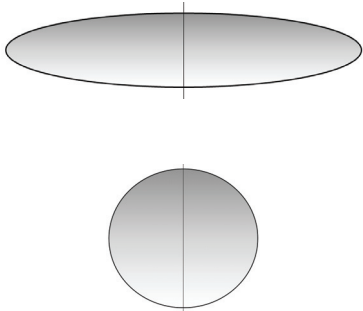
Swept Forward Planform



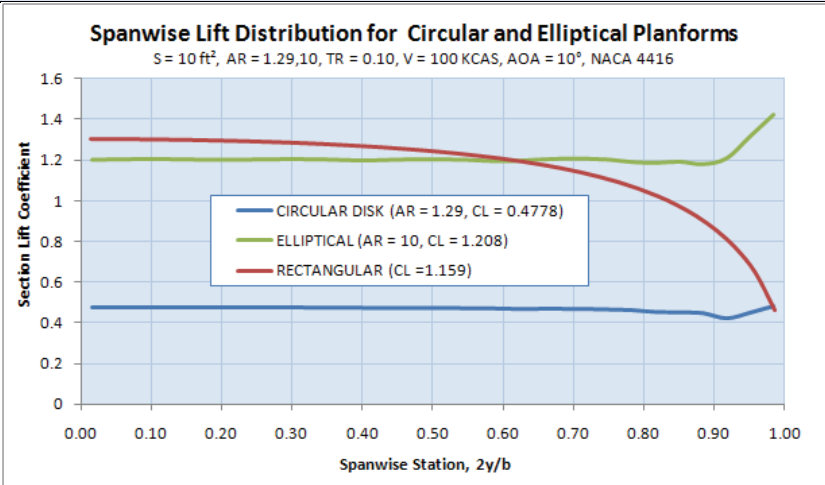
Example of use: Dornier Do-228, Stemme S-10



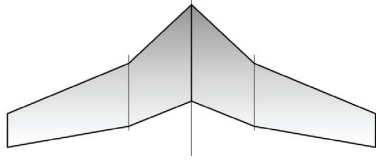
Elliptical and Disk Planform Shapes



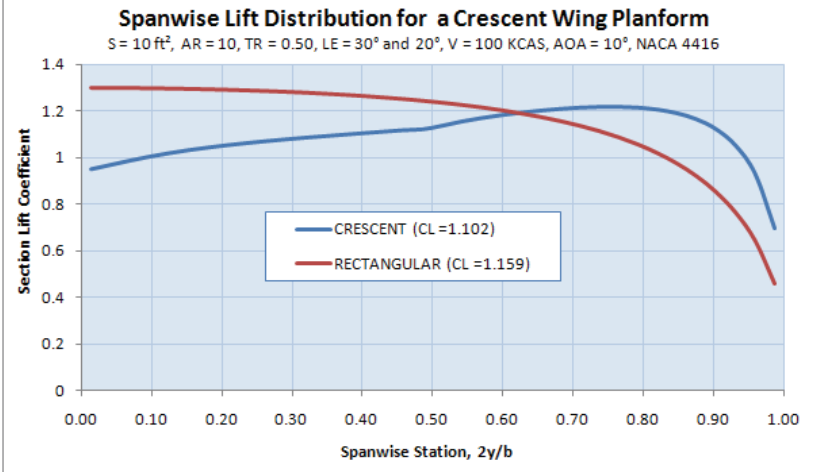
Example of use (elliptical): Supermarine Spitfire
 Example of use (disk): AVRO Canada VZ-9A (nicknamed the "AVRO car")



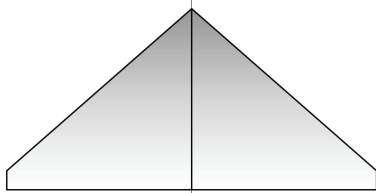
Crescent Planform



Example of use: Handley-Page Vulcan

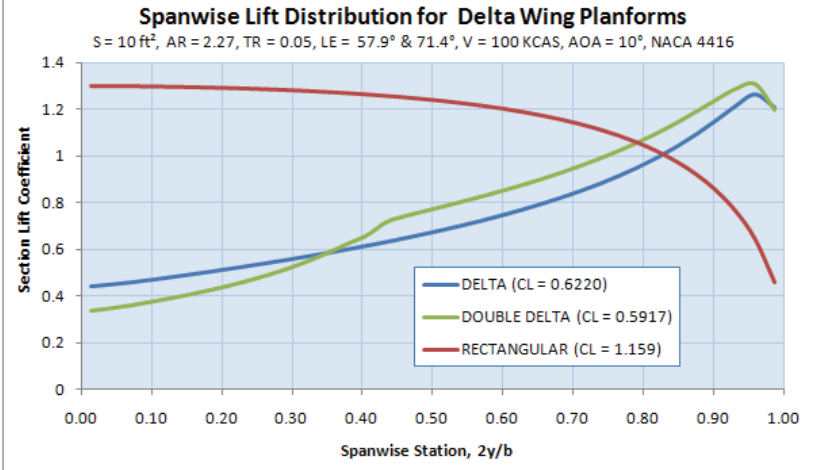


Delta and Double-Delta Planform Shapes



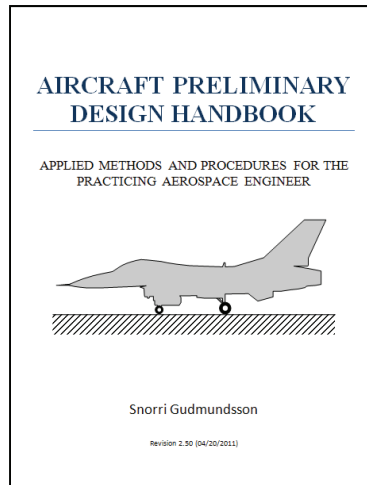
Example of use (delta): Dassault Mirage III

Example of use (double-delta): SAAB J-35 Draken, General Dynamics F-16 "Cranked Arrow"



WHAT IS ProAdvice?

Pro-Advices are short and simplified excerpts from Professor Gudmundsson's design handbook *Aircraft Preliminary Design Handbook* and are intended to provide the aircraft designer with clear and concise analysis methods for the aircraft designer. This handbook is currently in development. Snorri Gudmundsson is an Assistant Professor of Aerospace Engineering at Embry-Riddle Aeronautical University in Daytona Beach, Florida, where he teaches Aircraft Preliminary Design to senior engineering students.



ANALYSIS 2: General Climb Angle

Computed from:
$$\sin \theta = \frac{T}{W} - \frac{f(S)}{W} C_{D_{\text{min}}} - k \left(\frac{W}{S} \right) \frac{\cos^2 \theta}{q} \quad (14-14)$$

General angle:
$$\sin \theta = \frac{1}{L/D} \quad (14-15)$$

DERIVATION:
To get Equation (14-14), divide with V on either side of Equation (14-13):

$$T \sin \theta = T \left(\frac{T}{W} - \frac{f(S)}{W} \right) C_{D_{\text{min}}} - k \left(\frac{W}{S} \right) \frac{\cos^2 \theta}{q}$$

To get Equation (14-15), divide with V on either side of Equation (14-12):

$$T \sin \theta = \frac{TV - DV}{W} \Rightarrow \sin \theta = \frac{T}{W} - \frac{D}{W} = \frac{T}{W} - \frac{D}{L} = \frac{T}{W} - \frac{1}{L/D}$$

EXAMPLE 14.8:
Determine the angle of climb for the sample aircraft flying at 250 KCAS at S-1 at maximum thrust and at a weight of 20,000 lb.

Dynamic pressure: $q = \frac{1}{2} \rho V^2 = \frac{1}{2} (0.002378) (250 \times 1.688)^2 = 211.7 \text{ lb}_f/\text{ft}^2$

$$\sin \theta = \frac{T}{W} - \frac{f(S)}{W} C_{D_{\text{min}}} - k \left(\frac{W}{S} \right) \frac{\cos^2 \theta}{q}$$

$$= \left(\frac{7000}{20000} \right) - \left(\frac{211.7}{20000} \right) (0.020) - \left(0.05236 \left(\frac{20000}{311.6} \right) \frac{1}{(211.7)} \right)$$

$$= (0.35 - 0.065966 - 0.019875) = 0.264158$$

This amounts to 15.4°.

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