

1. An aerodynamic analysis program is run to assess the longitudinal stability of a new design. The untapered, unswept wing has a span of 10 ft, a chord of 1 ft. An unswept aspect ratio 5 tail is located 3 chords aft of the wing. Here are the results, all nondimensionalized based on wing area and chord.

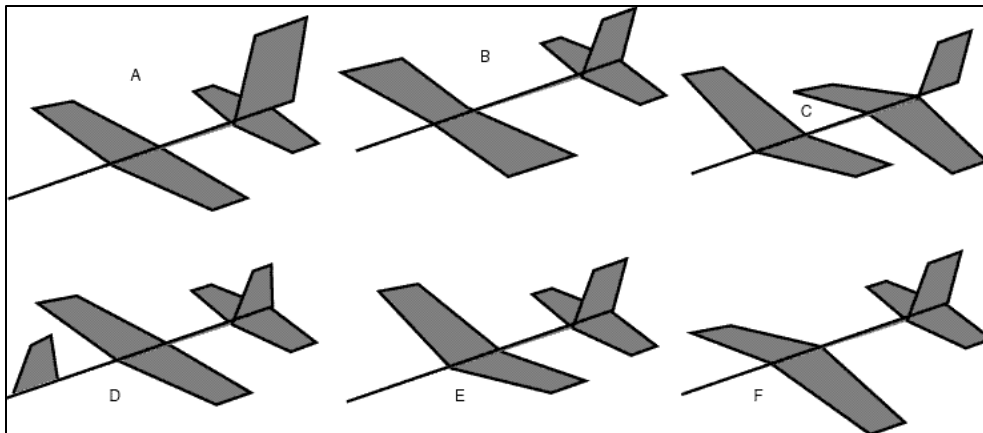
Case 1: $\alpha=0$, elevator=0, $C_L=.1625$, $C_m=.0239$, $C_{L_{wing}}=.1705$, $C_{L_{tail}}=-.0079$

Case 2: $\alpha=1$, elevator=0, $C_L=.2588$, $C_m=-.0053$, $C_{L_{wing}}=.2571$, $C_{L_{tail}}=.0017$

Case 3: $\alpha=0$, elevator=1, $C_L=.1777$, $C_m=-.0173$, $C_{L_{wing}}=.1719$, $C_{L_{tail}}=.0057$

The moment is measured about the (unknown here) reference c.g. location.

- What is the static margin?
 - Where is the aerodynamic center located (in feet aft from the reference c.g. location)?
 - Estimate the elevator deflection required to trim at $C_L = .5$
 - Estimate the airplane $C_{m_{ac}}$.
2. For the configurations shown below with equal wing spans and areas select the design that most likely:
- Has positive $C_{l\beta}$
 - Has negative $C_{n\beta}$
 - Has the largest C_{lp}
 - Has the largest C_{mq}
 - Has a negative value of C_{lr}



3. a. Compute the aileron deflection required to trim in a 60 sec steady turn with 30 deg bank angle for an F-100 fighter with no rudder input and with the following stability derivatives. (Hint: A 60 second turn means $d\Psi/dt = 2\pi/60$ rad/sec and for this case $p = 0$ and $r = d\Psi/dt \cos \Phi$).
- $C_{n\beta} = 0.15$ $C_{l\beta} = -0.10$ $C_{nr} = -0.27$ $C_{lr} = 0.12$ $C_{n\dot{\alpha}} = 0.00$ $C_{l\dot{\alpha}} = 0.10$
- b. Is the airplane spirally stable?

4. A linear dynamics analysis was run and the eigenvalues are shown below. One of the modes is unstable. Given the following derivatives, can you suggest whether it is the phugoid, spiral, dutch roll, short period, or roll mode that is most likely the problem?

Derivatives		Eigenvalues			
		Mode			
CL_ref	0.6				
CD_ref	0.06	1	-2.7914	+ 5.0020	i
CLalpha	5.92	2	-2.7914	+ -5.0020	i
CDalpha	0.0	3	-0.0033	+ 0.5516	i
Cmalpha	-1.49	4	-0.0033	+ -0.5516	i
CLq	15.98	5	0.4526	+ 3.8279	i
CDq	0.2	6	0.4526	+ -3.8279	i
Cmq	-6.0	7	-3.3598	+ 0.0	i
CYbeta	-0.886	8	-0.02345	+ 0.0	i
Clbeta	-0.2				
Cnbeta	0.05				
CYp	-0.041				
Clp	-0.0607				
Cnp	-0.1044				
CYr	0.285				
Clr	0.164				
Cnr	-0.0887				

5. For an unswept flying wing with high aspect ratio, we would like to trim using supercritical airfoils that have $C_{m_{ac}} = -0.10$. This will require that the airplane be unstable. The elevator is a flap at the trailing edge that produces a change in CL of 0.05 per deg of elevator and a change in $C_{m_{a.c.}}$ of -0.0225 per degree of elevator.
- Compute the static margin if the airplane is to trim without control deflections at $CL = .5$.
 - The idea is to provide artificial stability by deflecting the elevator in proportion to angle of attack. Compute the important derivative $C_{m_{\delta}}$ in this case. Is this idea feasible?
6. The (uncontrolled) longitudinal dynamics of an airplane that is free only to pivot about its c.g. (1 degree of freedom) are similar to those of an airplane that is allowed to pitch and plunge (2 degrees of freedom) if the pivoted airplane C_{m_q} is related to the free airplane C_{m_q} by: $C_{m_q-1dof} = C_{m_q-2dof} + i_{yy} C_{z_{\alpha}} / 2\mu$ and the pivoted airplane $C_{m_{\alpha}}$ is related to the free airplane $C_{m_{\alpha}}$ by: $C_{m_{\alpha}-1dof} = C_{m_{\alpha}-2dof} + X$. Find an expression for X in terms of $C_{m_{\alpha}}$, C_{z_q} , C_{m_q} , $C_{z_{\alpha}}$, and μ for the free (2DOF) airplane.

7. Indicate which of the following statements are true. If you are unsure you may write a brief argument that may lead to partial credit.
- a. Normally-designed upward-facing winglets on an unswept wing tend to be destabilizing in yaw while downward winglets add yaw stability at small angles of sideslip.
 - b. The fuselage tends to produce a negative increment to Cm_{α} , leading to increased stability compared with the wing-tail combination alone.
 - c. Cn_p tends to be negative due to the tilting of the lift vector relative to the body axes. But this is true only at positive CL. For an untwisted wing at zero lift the net yawing moment due to roll rate is zero.
 - d. The stabilizing influence of the tail is reduced due to the effect of wing downwash. This is more severe for low aspect ratio wings and for tails that are near the wing wake (as opposed to T-Tails, for example).
 - e. A flying wing may achieve stable trimmed flight only by achieving a positive value of Cm_{ac} . This may be done either with sweep and twist or with reflexed airfoil sections.
 - f. Three factors that lead to the presence of u derivatives are: Mach effects, aeroelasticity, variation of force in proportion to dynamic pressure.
 - g. An oblique wing with the right wing swept forward would roll to the right at low angles of attack due to the loading up of the aft wing, in the same way that the tips of aft swept wings tend to load up faster than the tips of forward swept wings.
 - h. In reality the aerodynamics of an airplane undergoing arbitrary motion depend on the history of the motion, not just the instantaneous values of alpha, q, $d\alpha/dt$, etc. So when we write the forces as the sum of terms related to the stability derivatives, this is just an approximation.
 - i. When integrating the equations of motion directly in time (as in assignment 6), Sam found that with $Cm_{\alpha} = -.2$, initial $w=1$ ft/sec, initial $U = 100$ ft/sec, $dt = 0.5$ sec, $Cz_{\alpha} = -4.5$, $I_{yy} = 20$ sl ft², his airplane went unstable. This is probably due to the value of Cm_{α} that he used.
 - j. Airplanes with large dihedral and small vertical tails are likely to be unstable in the spiral mode.