The University of Texas at Austin
Aerospace Engineering
and Engineering Mechanics
Cockrell School of Engineering

19 SEPTEMBER 2024

ASE 367K: FLIGHT DYNAMICS

TTH 09:30-11:00
CMA 2.306

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Topics for Today

- Topic(s):
  - Roll Stiffness (cont'd)
  - Roll Control
  - Roll Stiffness/Control Problem

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ROLL STIFFNESS

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resistance to roll. Tendency to go back to equilibrium

Wing sweep and dihedral gives roll stiffness
Fin too

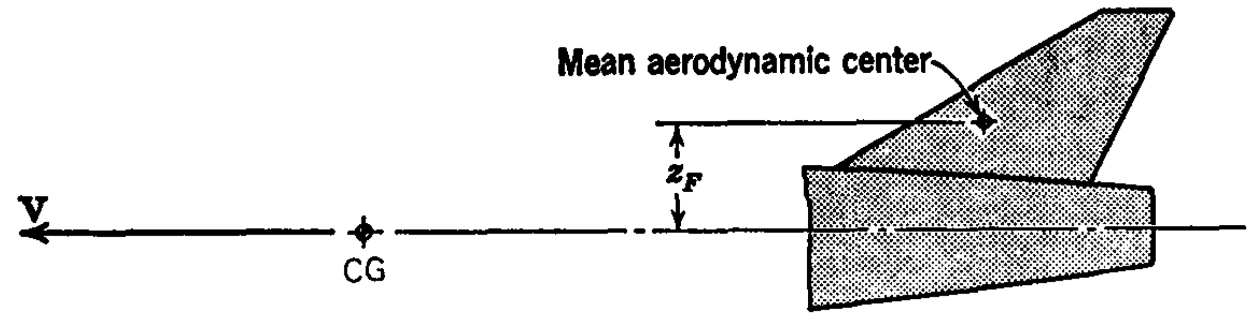
Roll Stiffness (8)

l m n

- Sideslipping gives rise to a side force on the vertical tail.
- When the mean aerodynamic center of the vertical surface is appreciably offset from the rolling axis then this force may produce a significant rolling moment.
- When the rudder angle is zero, this moment is…

[redacted] $= \frac{1}{2}\rho {V_F}^2 S_F a_F(-\beta+\sigma) z_F$

L



- The moment coefficient is…

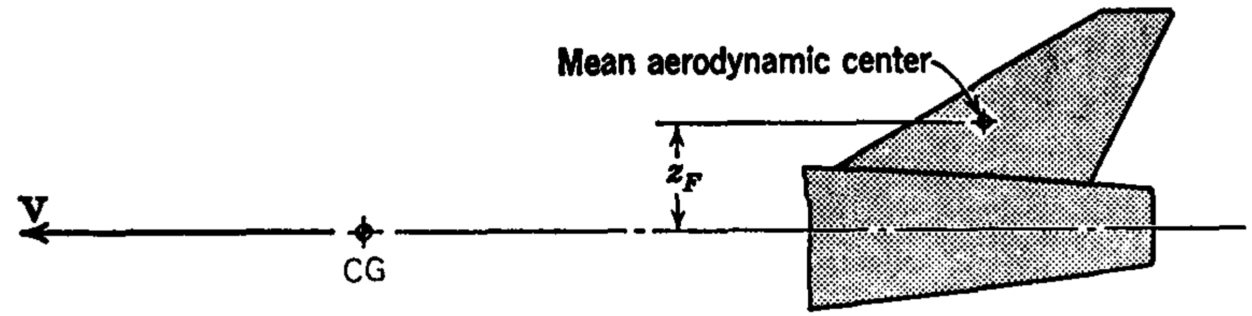
[redacted] $= a_F(-\beta+\sigma)\frac{S_F z_F}{Sb}\left(\frac{V_F}{V}\right)^2$

and the contribution to the roll stiffness is…

[redacted]$C_{l_\beta} = -a_F\left(1-\frac{\partial\sigma}{\partial\beta}\right)\frac{S_F z_F}{Sb}\left(\frac{V_F}{V}\right)^2$

Roll Stiffness (9)

- If the rudder gets stuck at its maximum deflection, the moment that is created can cause the airplane to flip over…



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ROLL CONTROL

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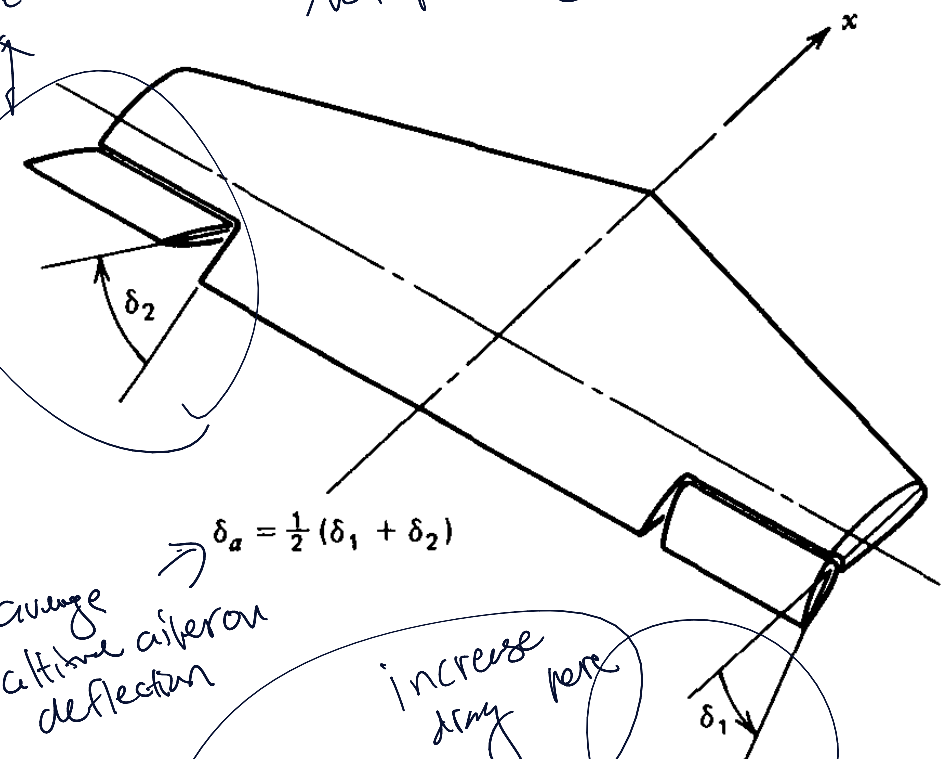
Roll Control (1)

- The bank angle is controlled by the ailerons.
  - They produce a rolling moment, although they frequently introduce a yawing moment as well.
- The effectiveness of the ailerons is described by the two control derivatives.
  - $C_{l_{\delta_a}}$ - effectiveness in producing roll ← want it
  - $C_{n_{\delta_a}}$ - effectiveness in producing yaw ← want it big too.
- The aileron angle δ_a is defined as the mean value of the angular displacements of the two ailerons.
  - Positive when right aileron is deflected downward.
- The derivative $C_{l_{\delta_a}}$ is normally negative.
  - Right aileron down produces a roll to the left.

reduce lift

ailerons Not perfectly aligned



average cultitive aileron deflection

increase drag here

creates yaw

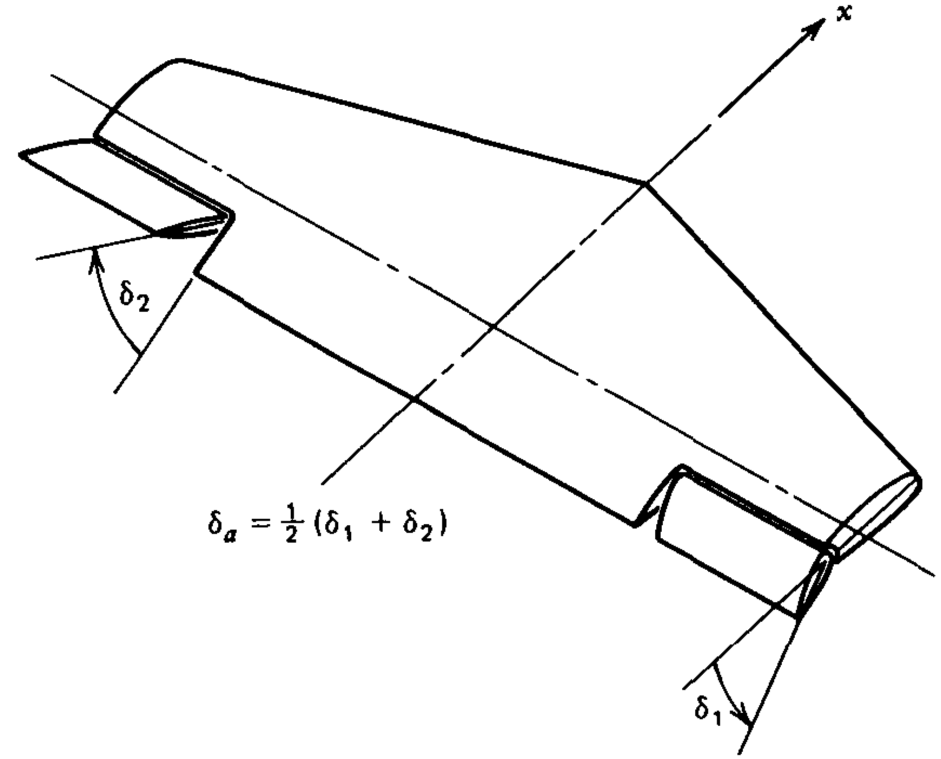
this drag is causing yaw in the opposite direction.

increase lift

Roll Control (2)

more lift = more induced drag .

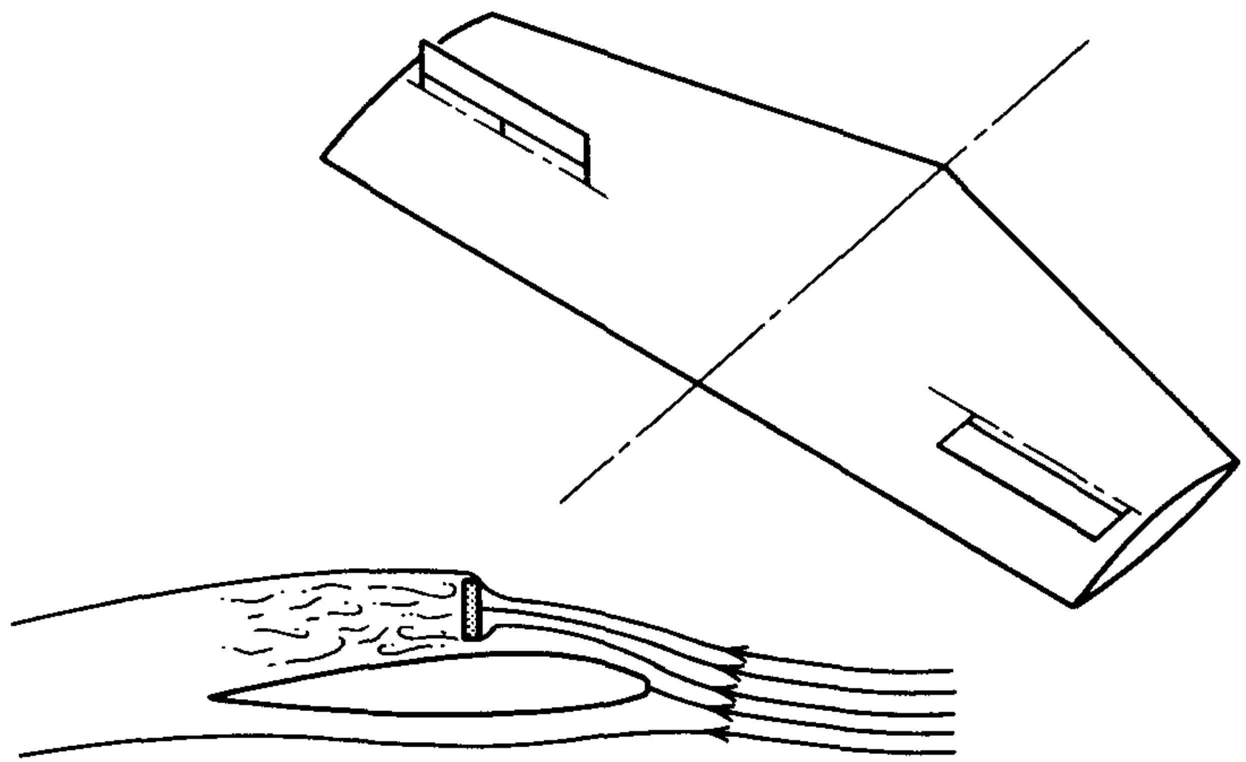
- For simple flap-type ailerons, defecting the right aileron down and the left aileron up produces an increase in the lift on the right side and a decrease in the lift on the left side, thereby produce a drag differential that causes a positive (nose-right) yawing moment.
- This is referred to as aileron adverse yaw.
  - Since the normal reason for moving the right aileron down is to initiate a turn to the left, then the yawing moment is seen to be in just the wrong direction.
- On high-aspect-ratio airplanes this tendency may introduce decided difficulties in lateral control that are avoided via the use of spoilers and Frise ailerons.



Roll Control (3)

2 ways to counter adversiv.

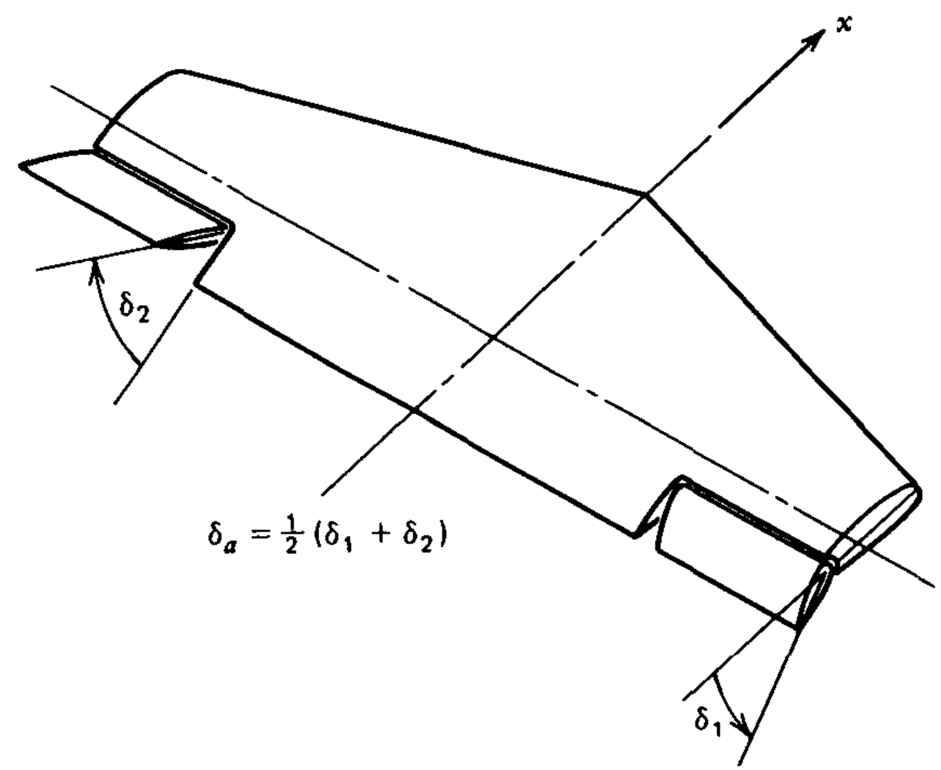
- Spoilers (see figure) achieve the desired result by reducing the lift and increasing the drag on the side where the spoiler is raised, making the rolling and yawing moments mutually complementary with respect to turning.
- Frise ailerons diminish the adverse yaw or eliminate it entirely by increasing the drag on the side of the upgoing aileron.
  - This is achieved by the shaping of the aileron nose and the choice of hinge location.



Section through spoiler

Roll Control (4)

- Ailerons are functionally distinct from the elevators and rudder.
  - Aileron are rate controls, i.e., if the airplane is restricted only to rotation about the x axis, then the application of a constant aileron angle results in a steady rate of roll.
  - The elevators and rudder are displacement controls, i.e., when the airplane is constrained to the relevant single axis degree of freedom, a constant deflection of these controls produces a constant angular displacement of the airplane



elevator rudder = when we set them we set new equilibrium but ailerons do not set equilibrium, you make it keep spinning. Gives you a rate.

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ROLL STIFFNESS/CONTROL PROBLEM

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Roll Stiffness/Control Question 1 (1)

Develop an expression for the wing dihedral effect C_{l_β} for a wing planform that uses dihedral only for the outboard portion of the wing (see Figure P2.18). Clearly state all of your assumptions.

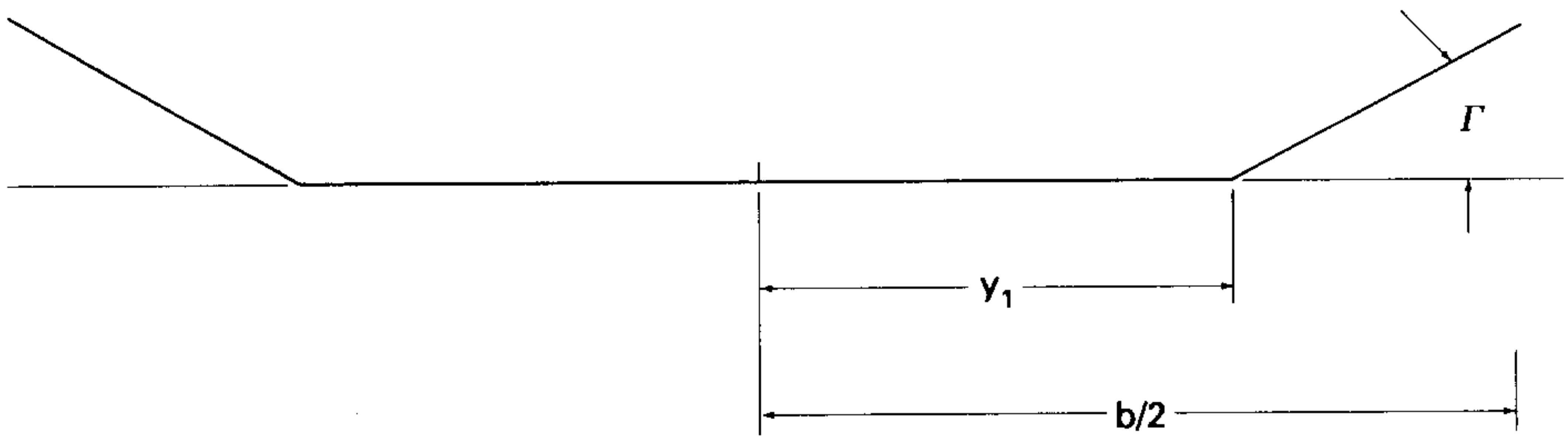


FIGURE P2.18

Roll Stiffness/Control Question 1 (2)

The wing dihedral creates a restoring moment if the wing is disturbed from a wings level attitude.

the local change in wing angle of attack was:

$\Delta\alpha = \beta\Gamma$ for the downward wing

$\Delta\alpha = -\beta\Gamma$ ——— upward ——

the incremental roll moment can be expressed:

$$dL = -y\, dLift = -y\, C_L\, Q\, c\, dy = -y\, C_{L_\alpha}\, \Delta\alpha\, Q\, c\, dy$$

Roll Stiffness/Control Question 1 (3)

the non-dimensional coefficient is:

$$dC_\ell = \frac{dL}{QSb} = \frac{-C_{L\alpha}\Delta\alpha \cancel{Q} c\, y\, dy}{\cancel{Q} S b}$$

$$C_\ell = -2\frac{C_{L\alpha}}{Sb}\beta\Gamma\int_{y_1}^{b/2} c\, y\, dy$$

for both sides of the wing

$$\boxed{C_{\ell_\beta} = -\frac{2C_{L\alpha}}{Sb}\Gamma\int_{y_1}^{b/2} c\, y\, dy}$$

moment around ℓ, $C_{\ell\beta}$

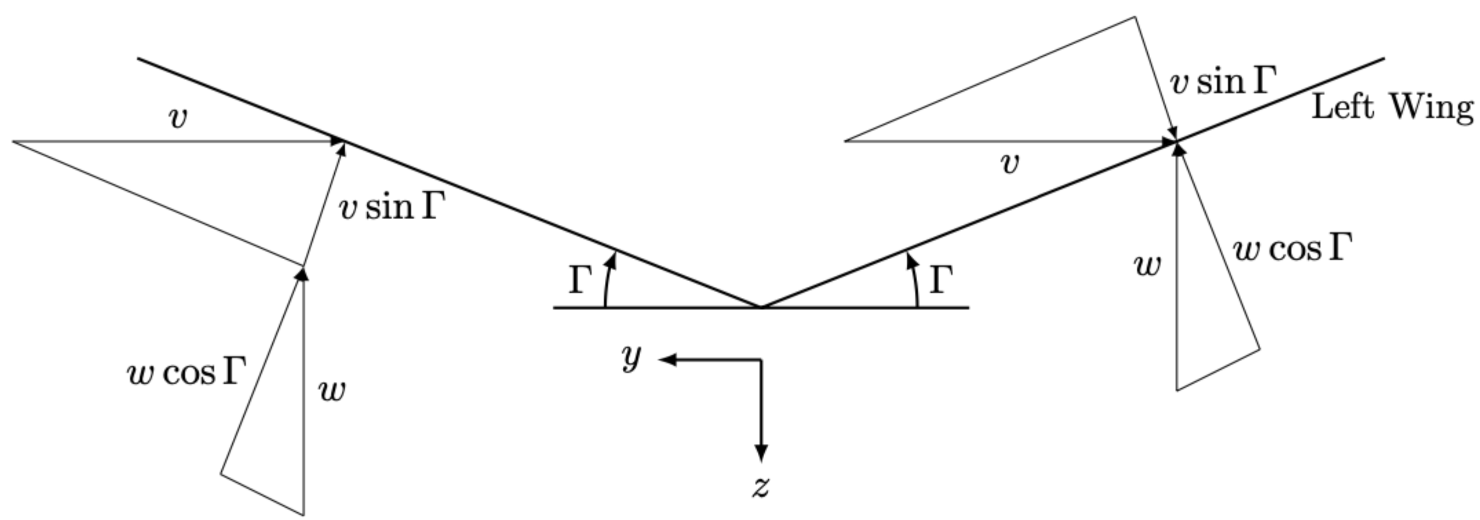
linear with Γ

exam

Roll Stiffness/Control Question 2

The derivative C_{l_β} depends on the fin geometry, the wing dihedral, the wing sweep and the wing placement relative to the fuselage. At the design stage, changing the dihedral is an effective way to alter C_{l_β} with little to no effect on the aircraft's weight or CG. For a rectangular wing with $C_{L_{\alpha_w}} = 5.9$ [rad^{-1}], determine the dihedral contribution to C_{l_β} when the dihedral is 5 [deg].

$$C_{l_\beta} = -\frac{y_{ac_w}}{b} C_{L_{\alpha_w}} \Gamma = -\frac{1}{4} C_{L_{\alpha_w}} \Gamma = -0.1287$$



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