ASEN 3728 Aircraft Dynamics
Written Homework 6

Due date listed on Gradescope.

Question 1. TRUE or FALSE: Consider an aircraft designed with typical stabilizing dihedral effect. If the wind that this aircraft is flying into suddenly changes so that the sideslip angle β suddenly becomes positive, the immediate reaction of the aircraft in the roll direction will be a positive roll ($p > 0$) into the wind. Justify your answer.

Question 2.

1. Estimate the required bank angle, ϕ, *in degrees* that are needed for a Boeing 747 to maintain a steady level coordinated turn that completes a full circle every three minutes at sea level and a speed of 221 ft/s (Case I in Appendix E).

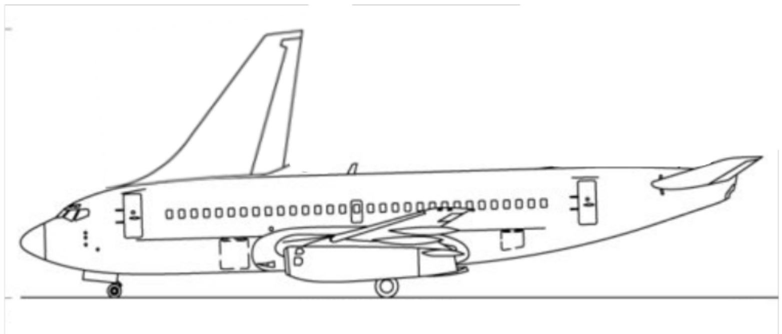
2. Find the wind angles, $\Delta\alpha$ and β, and control inputs δ_a, δ_r, and $\Delta\delta_e$, *all in degrees* needed to maintain this turn. The nondimensional derivatives can be found in Table 6.1, 6.6, and 7.3, and physical parameters can be found in Appendix E of the textbook. The following lines of code can be copied and pasted to save some typing if you can figure out how to use them:

```
[-0.8771  0.1146 0; -0.2797  6.976e-3 -1.368e-2; 0.1946 -0.1257 -1.973e-4]
[-1.023 -1.444; 4.920 0.3648]
[0 0; -0.3295   0.304; -0.04073 -0.2737]
[-23.92; 5.921]
```

   You can either include code in your submission or describe, with equations, how you calculated these angles without submitting code.

3. Does the sign of the aileron input required to *sustain* this turn match the sign of the aileron input required to *initiate* the turn from steady level flight? Explain your answer.

Question 3. Consider the experimental aircraft shown below with a vertical stabilizer located a distance l_F forward of the center of gravity.



1. Re-derive the yaw stiffness contribution from the vertical stabilizer, $C_{n_{F\beta}} = \frac{\partial C_{n_F}}{\partial \beta}$. Let the sidewash angle, σ, and $\frac{\partial \sigma}{\partial \beta}$ be 0. Thus, $\alpha_F = -\beta$. What is the sign of $C_{n_{F\beta}}$?
2. Re-derive the "rudder power" $C_{n_{\delta_r}}$.
3. Is this a good aircraft design? Why or why not?

Question 4. While flying near sea-level at $u_0 = 10$ m/s, the TTwistor aircraft from homework P3 has the lateral dynamics matrix shown below.

$$\mathbf{A}_{lat} = \begin{bmatrix} -0.2472 & -0.0671 & -9.7797 & 9.8100 \\ -0.7966 & -16.5375 & 1.8114 & 0 \\ 0.4607 & -0.3451 & -0.4586 & 0 \\ 0 & 1.0000 & 0 & 0 \end{bmatrix}$$

Assume for this analysis that the aircraft's inertia matrix is diagonal, so that only I_x, I_y, and I_z are non-zero. This means that $\Gamma_3 = 1/I_x$, $\Gamma_4 = 0$, and $\Gamma_8 = 1/I_z$.

1. Calculate the time constant ($\tau_{roll} = 1/|\lambda|$) of the roll mode and the natural frequency $\omega_{n,dr}$ of the Dutch roll mode.

2. Recall that nine lateral dimensional stability derivatives appear in the expression for $\mathbf{A}_{lat}$. One-by-one, increase the value of each dimensional stability derivative by 10% and calculate the new time constant of the roll mode and new natural frequency of the dutch roll mode. So, first, increase Y_v by 10% and calculate the new values of τ_{roll} and $\omega_{n,dr}$. Then, return Y_v to its original value and increase the next stability derivative by 10%. You do not need to report every value that you calculate, but do answer the following:

   (a) A change in which stability derivative decreases the time constant of the roll mode the most? What is the new time constant when this derivative is increased by 10%?

   (b) A change in which stability derivative increases the natural frequency of the Dutch roll mode the most? What is the new natural frequency when this derivative is increased by 10%?

3. Qualitatively explain why the two stability derivatives you identified in the previous part have the largest effect on τ_{roll} and $\omega_{n,dr}$ using characteristics of the roll and Dutch roll modes.