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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

V SEMESTER B.TECH. (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, NOV/DEC 2019

SUBJECT: FLIGHT DYNAMICS [AAE 3101]

REVISED CREDIT SYSTEM
(27/11/2019)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitable assumed.

1A. The Piaggio P-180 Avanti II, see figure 1, has an unusual combination of a canard surface and a T-tail. The aircraft is schematically drawn in the figure 2 below: **(08)**

Figure 1

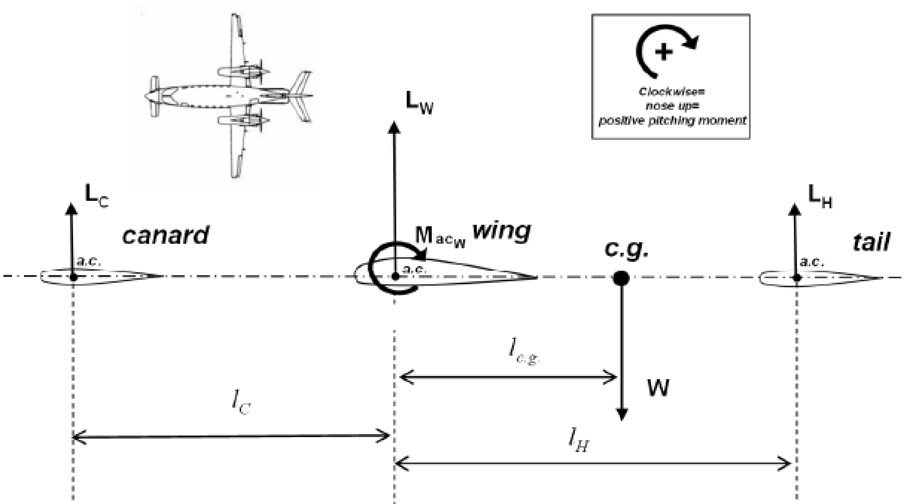

Figure 2

As for any aircraft, for longitudinal static stability two conditions have to be met:

1. When $C_L = 0, C_{m_0} > 0$.
2. Answer the following carefully:
   a) What does the second condition require for the coefficient C_{m_α}?
   b) Show that

$$C_{m_\alpha} = C_{L_\alpha}\frac{l_{cg}}{c} + C_{L_{\alpha_{Canard}}}V_{Canard} - C_{L_{\alpha_{Tail}}}\left(1 - \frac{d\varepsilon}{d\alpha}\right)V_H$$

The canard and tail use the same, symmetrical airfoil and have the same C_{L_α} relation. Also given is that $\frac{d\varepsilon}{d\alpha} = 0.05$ is very small because it is a T-tail. Noting that the canard is smaller than the tail, but the distance wing-canard is similarly larger than the distance wing-tail, we assume for now that the canard volume is equal to the tail volume i.e. $V_{Canard} = V_H$.

   c) Prove that the aircraft is unstable when the center of gravity is at the aerodynamic center of the main wing.
   d) Should the center of gravity be moved closer to the nose or to the tail for more stability? Why? Use the expression given in (b).
   e) Not all canard aircraft have a tail surface as well. What would be the main advantage and disadvantage of adding the tail to the canard configuration?

1B. Which type of derivatives characterized lag in the development of downwash at the horizontal tail and how? **(02)**

2A. Wing-body $\left(C_{l_{\beta_{WB}}}\right)$ provides a significant contribution to C_{l_β} because the dihedral effect of the wing fuselage combination is caused by three factors **(05)**

1. Wing geometric dihedral effect.
2. Effect of wing position on the fuselage (high or low)
3. Effect of wing sweep angle.

Explain in brief each of these effects with suitable diagrammatical representation.

2B. Using aircraft dynamic equations for the following aircraft, find $\dot{u}$ for a positive 1-deg step elevator input at $t = \infty$. **(03)**

$X_{\delta_E} = 12.3976$ ft/s^2 $X_{T_u} = -0.0123$ s^{-1} $X_u = 0.0085$ s^{-1}

$X_\alpha = -4.9591$ ft/s^2 $U_1 = 876$ ft/s

2C. Explain how an aft wing sweep provides a positive significant contribution to derivative C_{n_β}. **(02)**

3A. Find the lateral eigenvalues of the general aviation airplane, identify the modes, comment on stability and compare the results spiral mode with the answers obtained using the lateral approximations. **(05)**

$Y_\beta/u_0 = -0.254$ $\quad L_\beta = -16.02\ \text{s}^{-2}$ $\quad N_\beta = 4.49\ \text{s}^{-2}$

$Y_p = 0$ $\quad L_p = -8.4\ \text{s}^{-2}$ $\quad N_p = -0.35\ \text{s}^{-1}$

$Y_r = 0$ $\quad L_r = 2.16\ \text{s}^{-1}$ $\quad N_r = -0.76\ \text{s}^{-1}$

$$g/u_0 \cos\theta_0 = 0.182$$

3B. A T-37 is executing a loop at the following conditions: **(03)**

Euler angles: $\psi = 30^0;\ \theta = 60^0;\ \emptyset = 0^0.$

The pilot observes a pure pitch rate at a constant velocity in the body axis system:

$$\vec{\omega}_B = \begin{bmatrix} 0 \\ 0.5 \\ 0 \end{bmatrix} \text{rad/s} \qquad \vec{v}_B = \begin{bmatrix} 300 \\ 0 \\ 0 \end{bmatrix} \text{ft/s}$$

What is the acceleration in the Earth-fixed reference system?

3C. Is it true that the neutral point location is almost always aft of the wing body aerodynamic center? **(02)**

4A. Figure 3 below shows the change in the lift distribution across the wing produces a rolling moment that opposes the rolling motion and is proportional to the roll rate meaning the negative rolling velocity induces a positive rolling. **(05)**

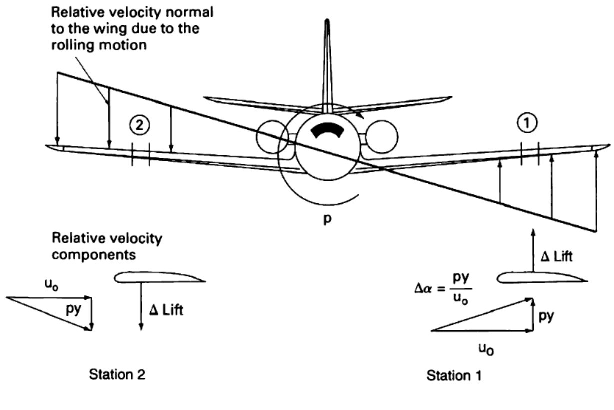

Figure 3

Show that the roll damping derivative is

$$C_{l_p} = -\frac{4C_{L_{\alpha W}}\tau}{Sb^2}\int_0^{b/2} cy^2 dy$$

4B. Given the following nonlinear differential equation that represents some fictitious EOM for a vehicle: **(03)**

$$\dot{A} + BU = X$$

Linearize the equation using the small perturbation approach of the EOM and the same steps and assumptions used to develop the real aircraft EOM.

4C. Explain what happens when the asymmetric side force is developed on the wing tip due to perturbed positive roll rate. **(02)**

5A. The right engine on an aircraft with two $10{,}000$ lbf thrust engines fails. The aircraft is at sea level. **(05)**

$C_{n_\beta} = 0.002$ deg^{-1}	$S = 300$ ft^2	$b = 50$ ft
$C_{n_{\delta_R}} = -0.0033$ deg^{-1}	$q = 100$ lb/ft^2	$y_e = 5$ ft

a) If the pilot takes no corrective action, what will be the sideslip angle?
b) How many degrees and which direction should the pilot deflect the rudder to realign the nose with the relative wind?
c) If the max rudder deflection is 15^0, at what airspeed would the pilot no longer be able to maintain $\beta = 0^0$?

5B. Given the following equation for a mass–spring–damper system **(03)**

$$M\ddot{X} + C\dot{X} + KX = KY$$

Where system if assumed to be massless, spring initial displacement $Y = 10$ in, spring constant $K = 5$ lb/in and damping coefficient $C = 0.1$ lb-s/in. Given the initial condition, $X(0) = 2$, find

1. the complementary or transient solution
2. the particular or steady state solution
3. the general or total solution

5C. An aircraft has a lift curve slope of 0.12 deg^{-1} and a $C_{m_\alpha} = -0.05$ deg^{-1}. What is the aircraft's static margin? **(02)**

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