| Reg. No. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|

# MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
*A Constituent Institution of Manipal University*

## V SEMESTER B.TECH. (AERONAUTICAL ENGINEERING)

## END SEMESTER EXAMINATIONS, NOV/DEC 2016

SUBJECT: FLIGHT DYNAMICS [AAE 3101]

**REVISED CREDIT SYSTEM**
**(24/11/2016)**

Time: 3 Hours MAX. MARKS: 50

**Instructions to Candidates:**

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

1A. Consider the airplane wing shown in Figure 1.1 with the aileron located between span-wise stations $y_1$ and $y_2$. The inset of Figure shows a chordwise cross section of the wing with the airfoil section and the trailing edge aileron flap. The aileron effectiveness is measured by a parameter $\tau = \frac{\Delta\alpha}{\Delta\delta_A} = \frac{d\alpha}{d\delta_A}$. Show that (05)

$$C_{l_{\delta_A}} = -2\left(\frac{C_{l_\alpha}\tau}{Sb}\right)\int_{y_2}^{y_1} cydy$$

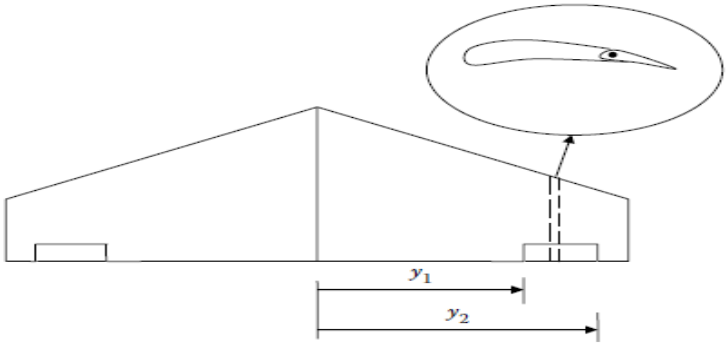


Figure 1.1

1B. For high-supersonic or hypersonic airplanes such as the SR-71 shown in figure 1.2, at high speeds, speed damping derivative can be negative and comparable in magnitude to $2C_{L_1}$. Does that mean, the phugoid mode is unstable? (03)

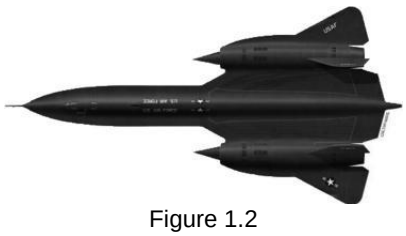

Figure 1.2

1C. The sign of $C_{y_\beta}$ for a conventional aircraft is negative and the dominant contribution to this stability derivative is made by the main wing. Is it true? (02)

2A. The dynamics of an aircraft is represented by the open loop transfer function as: (05)

$$G(s)H(s) = \frac{k}{s(s+4)(s^2+4s+20)}$$

Analyze the system by drawing a root locus and plotting the roots in S-plane for different values of parameters.

2B. With proper illustration, show that what is the effect of pitch rate perturbation about the center of gravity of an airplane (Slewing Velocities)? (03)

2C. Does yaw damper effects both yaw and roll rates in Dutch roll motion? How (02)

3A. The Douglas DC-8 aircraft state-space lateral-directional model is given as (05)

$$\begin{bmatrix} \dot{v} \\ \dot{p} \\ \dot{r} \\ \dot{\emptyset} \end{bmatrix} = \begin{bmatrix} -0.1 & 0 & -468 & 32 \\ -0.0058 & -1.232 & 0.397 & 0 \\ 0.0028 & -0.0346 & -0.257 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} v \\ p \\ r \\ \emptyset \end{bmatrix} + \begin{bmatrix} 0 & 13.48 \\ -1.62 & 0.392 \\ -0.00188 & -0.864 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \delta_A \\ \delta_R \end{bmatrix}$$

At the flight condition 4.57 km (15kft) and Mach 0.3, obtain the characteristic modes of the aircraft Dynamics, frequency response and comment on stability.

3B. Let us consider the wing and body alone of a general aviation plane. The wing body of the airplane has following properties: $C_{m_{AC}} = -0.04, \bar{x}_{AC} = 0.25, C_{L_\alpha} = 4.5\ rad^{-1}$. The C.G. of the airplane is located at a distance $\bar{x}_{CG} = 0.4$ (all distances are from the leading edge of the wing). Is it possible to trim this aircraft at positive angle of attack? (03)

3C. It is said that release of elevator has a destabilizing effect on the aircraft. Explain? (02)

4A. Determine the crosswind limit of SIAI Marchetti S211 aircraft assuming a final approach equivalent airspeed of 120 Kn and the following characteristics ($deg^{-1}$): (05)

$$C_{l_0} = 0 \quad C_{l_\beta} = -0.11 \quad C_{l_{\delta_A}} = 0.178 \quad C_{l_{\delta_R}} = 0.172$$
$$C_{n_0} = 0 \quad C_{n_\beta} = 0.127 \quad C_{n_{\delta_A}} = -0.0172 \quad C_{n_{\delta_R}} = 0.0747$$
$$\delta_{R_{max}} = \pm 20^0 \quad \delta_{A_{max}} = \pm 15^0$$

4B. Given $\begin{bmatrix} U \\ V \\ W \end{bmatrix} = \begin{bmatrix} 200 \\ 0 \\ 10 \end{bmatrix} \frac{ft}{s}$ in the body axis system with (03)

$$\emptyset = 25\ deg, \theta = 10\ \text{deg}\ and\ \psi = 0\ deg.$$

a) Find velocity components in earth axis system.
b) Show that this can be transformed back to body axis system.

4C. If say we shift the position of the center of gravity forward what will happen to the magnitude of the required control forces exerted by the pilot during normal operations? (02)

5A. The Republic F-105B Thunderchief aircraft as shown in figure 1.3, has a wing span of 10.6 m and is flying at a speed of 518 knots at an altitude, has a dimensionless controls fixed lateral–directional stability quartic as: (05)

$$\Delta(s) = s^4 + 29.3s^3 + 1052.7s^2 + 14913.5s - 1154.6 = 0$$

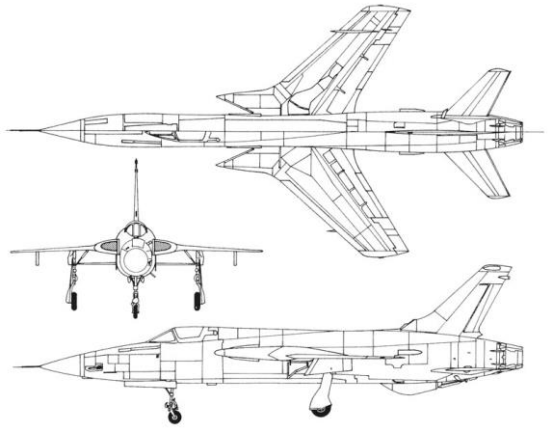

Figure 1.3

a) Inspect the characteristic equation above for stability using Routh-Hurwitz criterion.
b) Verify the stability by solving the characteristic equation.

5B. Calculate the change in CG required to trim the aircraft at $C_{L_{max}}$ with maximum up elevator deflection for the data given in Figure 1.4 and $C_{L_{max}} = 0.9$. (03)

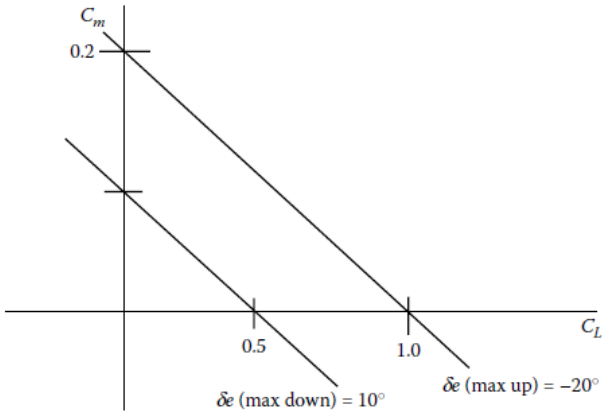


Figure 1.4

5C. Is it possible for you to make the spiral motion (more) stable while making the Dutch Roll motion unstable by increasing dihedral enough? (02)