Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

(A constituent unit of MAHE, Manipal)

V SEMESTER B.TECH. (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, NOV/DEC 2018

SUBJECT: FLIGHT DYNAMICS [AAE 3101]

REVISED CREDIT SYSTEM
(19/11/2018)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

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

1A. The following figure 1 is a block diagram for a roll control autopilot for a jet fighter: **(05)**

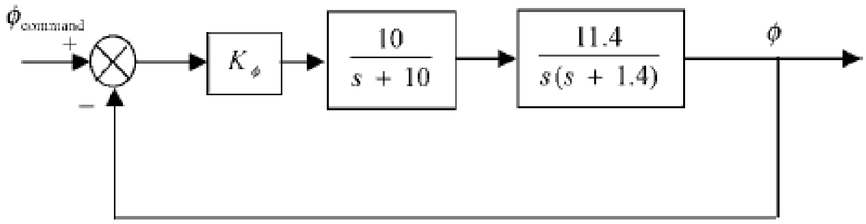

Figure 1

Determine the open loop and the closed loop transfer functions, the poles and zeros of the transfer functions. Sketch the root locus for this autopilot as the amplifier gain is varied from 0 to ∞. Be sure to determine the number of branches required, where it breaks away from the real axis and the gain where it crosses the imaginary axis.

1B. Assume a Lear Jet is cruising (level, un-accelerated flight) at $40{,}000$ ft with density at this altitude as 0.000588 slug/ft^3 and the following conditions: **(03)**

$$U_1 = 677 \text{ ft/s}, S = 230 \text{ ft}^2, W = 13{,}000 \text{ lb}, C_{T_{x_1}} = 0.0335.$$

a) Find C_{L_1} and C_{D_1}.
b) Compute the thrust being produced by the Lear Jet.

1C. Do you agree that cross derivative C_{n_p} has a relatively large influence on dynamic stability characteristics? **(02)**

2A. Consider the data for the McDonnell Douglas DC-9 aircraft given below. Assume that this aircraft features stabilators and elevators for the control of the longitudinal dynamics with $\tau_E = 0.5$ and $\eta_H = 0.9$. Using the modeling, find a numerical value for the following aerodynamic parameters: **(05)**

$C_{L_{\alpha_W}} = 6.062$ deg^{-1} $\quad C_{L_{\alpha_H}} = 4.741$ deg^{-1} $\quad S_H = 274.91$ ft^2 $\quad S = 928$ ft^2

$\bar{x}_{CG} = 0.3$ ft $\quad \bar{x}_{AC_{WB}} = 0.054$ ft $\quad \bar{x}_{AC_H} = 4.345$ ft $\quad \dfrac{d\varepsilon}{d\alpha} = 0.297$

Also estimate the value of aircraft aerodynamic center.

2B. Figure 2 below, shows airplanes 1 and 2 are flying at the trim point denoted by B. From this figure how can you conclude that, to have static longitudinal stability **(03)**

$$\frac{dC_m}{d\alpha} < 0$$

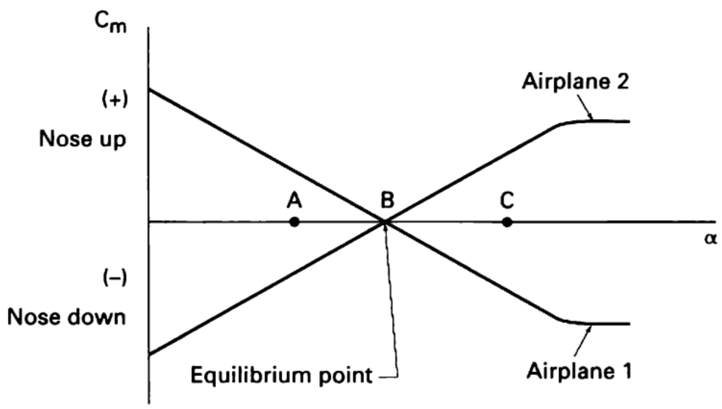

Figure 2

2C. Aileron control power $C_{l_{\delta_A}}$ is generally positive based on the definition of a positive aileron deflection. State at least two factors, which result in decreasing the derivative $C_{l_{\delta_A}}$. **(02)**

3A. Given the 2-DOF short period approximation, show that the angle of attack transfer function $\frac{\alpha(s)}{\delta_E(s)}$ is given as **(05)**

$$\frac{Z_{\delta_E} + (M_{\delta_E} V_{P_1} - M_q Z_{\delta_E})}{V_{P_1}\left\{s^2 + \left(M_q + \frac{Z_\alpha}{V_{P_1}} + M_{\dot{\alpha}}\right)s + \left(\frac{Z_\alpha M_q}{V_{P_1}} - M_\alpha\right)\right\}}$$

3B. A DC-9 is executing a loop at the following conditions: $\psi = 0^0$, $\theta = 30^0$, $\emptyset = 0^0$. The pilot observes a pure pitch rate at a constant velocity in the body axis system: **(03)**

$$\vec{\omega}_B = \begin{bmatrix} 0 \\ 0.1 \\ 0 \end{bmatrix}_B \text{ rad/s}, \ \vec{v}_B = \begin{bmatrix} 200 \\ 0 \\ 0 \end{bmatrix}_B \text{ ft/s},$$

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

3C. Roll helix angle gives significant contribution to roll damping derivative C_{l_p}. What is its physical meaning? **(02)**

4A. A T-37 has the following stability derivative values during a no-flap final approach at $100\ kn$ equivalent airspeed: **(05)**

$C_{l_\beta} = 0.11$ deg^{-1} $\qquad$ $C_{l_{\delta_R}} = 0.0172$ deg^{-1}

$C_{n_\beta} = 0.127$ deg^{-1} $\qquad$ $C_{l_{\delta_A}} = 0.178$ deg^{-1}

$C_{n_{\delta_R}} = -0.0747$ deg^{-1} $\qquad$ $C_{n_{\delta_A}} = -0.0172$ deg^{-1}

Assume that the pilot lands with the fuselage aligned with the runway. With $\delta_{R_{max}} = \pm 20$ deg and $\delta_{A_{max}} = \pm 15$ deg. What is the maximum crosswind component allowable and which is the limiting control (aileron or rudder)?

4B. Roll control in aircraft is achieved by ailerons on a wing located at span-wise stations $y_1 = 3.4\ m$ and $y_2 = 4.8\ m$ with the roll control power as: **(03)**

$$C_{l_{\delta_A}} = \frac{2C_{L_{\alpha_W}}\tau}{Sb}\int_{y_1}^{y_2} cy\,dy$$

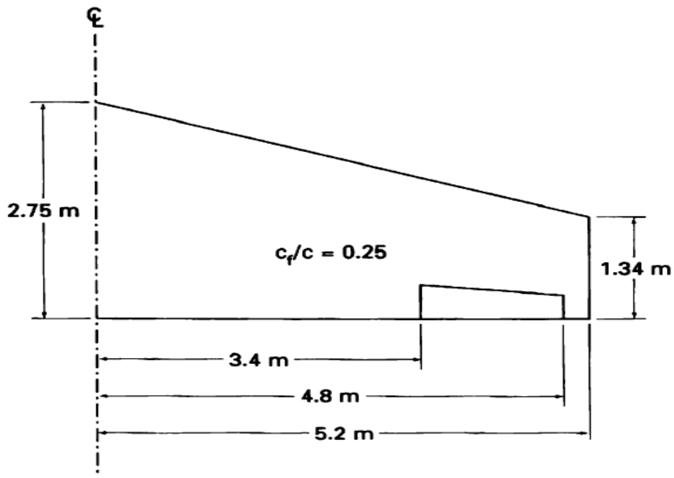

Figure 3

A wing planform for a business jet is given in figure 3 above. With chord $c = 2.75 - 0.27y$, $S = 21.3\ m^2, \tau = 0.48$ and assuming section lift coefficient to be 0.1 deg^{-1} . Using the strip theory, determine the roll control power.

4C. Normally, you would expect a fighter to have a higher or lower C_{l_p} than a glider? **(02)**

5A. Estimate the dynamic behavior of the DC-8 aircraft in a cruise-flight configuration which corresponds to $M = 0.84$, $h = 33{,}000$ ft, and $V = 825$ ft/s (TAS). The system matrix of the aircraft is given as: **(05)**

$$[A] = \begin{bmatrix} -0.0869 & 0.0 & 0.0390 & -1.0 \\ -4.424 & -1.184 & 0.0 & 0.335 \\ 0.0 & 1.0 & 0.0 & 0.0 \\ 2.148 & -0.021 & 0.0 & -0.228 \end{bmatrix}$$

Identify all the modes, find the frequencies and damping ratio of all the modes and comment on stability.

5B. With suitable diagrammatical representation, write all the steady-state longitudinal and lateral directional thrust forces and moments at nominal engine operating conditions. **(03)**

5C. As per $P^2 I_{XZ} = -I_{YY}\dot{Q}$, what will happen if the aircraft is doing a high speed flyby and suddenly rolls? **(02)**

****