Indian Institute of Engineering Science and Technology, Shibpur

B.E.(AE) 6th. Semester Final Examination, May 2014

Sub: Aircraft Stability and Control Sub. Code: **AE604**

Time: 3 hrs. Branch: **Aerospace Engineering and Applied Mechanics**

Answer any **<u>five</u>** questions Full Marks: **70**

Answer in **<u>single</u>** half only

Use linear graph paper for Question No. 1 and semi log graph paper for Question No. 2

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1. A feedback control system has an open-loop transfer function

$$G(s)H(s)=\frac{k(s+5)}{s(s^2+6s+10)}$$

Sketch the root locus on a graph-paper as k is varied from 0 to ∞. [14]

2. Construct the Bode plot on a semi log graph-paper for a unit feedback system whose open-loop transfer function is given by

$$G(s)=\frac{K}{s(s+2)(s+20)}$$

From the Bode plot determine (i) Limiting value of K for system to be stable (ii) Value of K for gain margin to be 10 dB (iii) Value of K for phase margin to be 50^0. [14]

3. (a) The open loop aircraft transfer function for pitch rate feedback to elevator is given by $\frac{q(s)}{\eta(s)}=\frac{-8.096s(s-0.0006)(s+0.3591)}{(s^2+0.014s+0.0068)(s^2+1.009s+5.56)}$ rad/s/rad. The corresponding Root Locus plot is shown in Fig. 1. Explain the Root Locus plot and discuss the stability of the aircraft. [7]

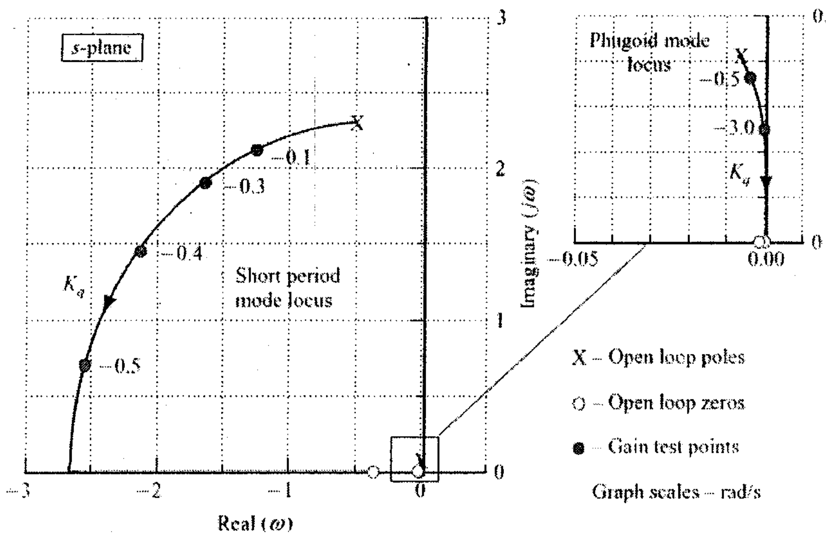

Fig. 1 Root locus plot for pitch rate feedback to elevator.

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(b) The frequency response of aircraft yaw rate to rudder input is shown by the Bode plot in Fig. 2. Identify the lateral dynamic modes of the aircraft and explain the stability. [7]

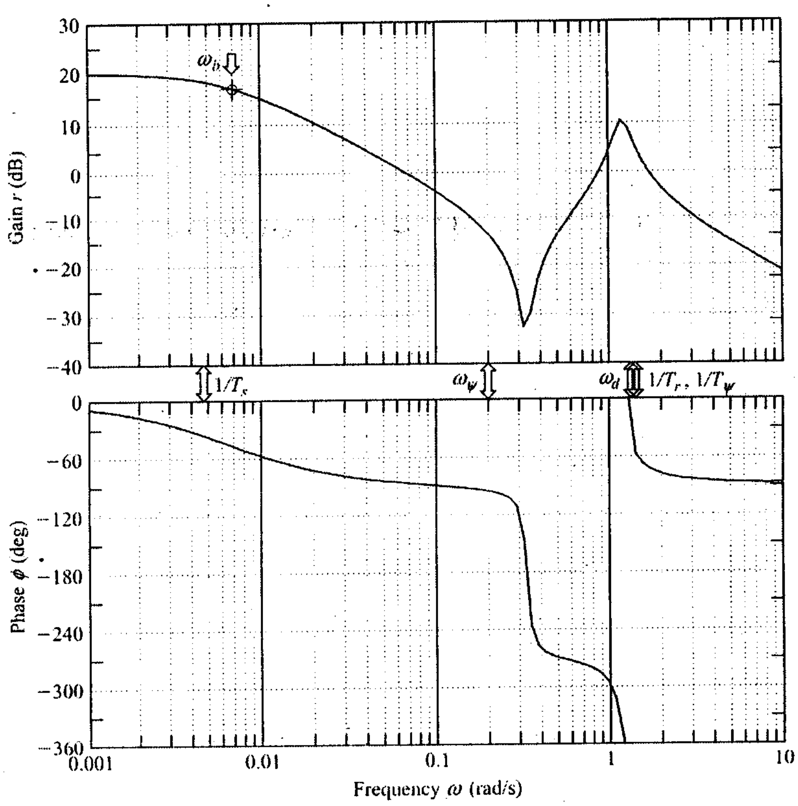

Fig. 2 DC-8 frequency response of yaw rate to rudder.

4. Write short note on any three of the following [14]

(a) Longitudinal directional flying quality requirements.
(b) Flight control system.
(c) Yaw damper for aircraft stability augmentation.
(d) Sensitivity analysis of aircraft dynamics.
(e) Mason's gain formula for signal flow graph.
(f) Phase Margin Expression for unit feedback control system with O.L.T.F. $G(s)=\dfrac{\omega_n^2}{s(s+2\zeta\omega_n)}$

5. Discuss the effect of CG location and moment of inertia of an aircraft on it's short period mode dynamics. Explain it by deriving the expression for short period modal frequency and damping ratio after solving longitudinal equation of motion using suitable approximation. [14]

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6. (a) By suitable approximation show that dutch roll mode frequency and damping ratio of an airplane can be expressed as, $\omega_{nd} = \sqrt{N_\beta}$ and $\zeta_d = \dfrac{-\left(N_r + \dfrac{Y_\beta}{V_{p1}}\right)}{2\omega_{nd}}$ [10]

Where, N_β is yaw angular acceleration per unit side slip angle, N_r is yaw angular acceleration per unit yaw rate, Y_β is lateral acceleration per unit sideslip angle, V_{p1} is true airspeed, ω_{nd} is dutch roll frequency and ζ_d is dutch roll damping ratio.

(b) Explain what will be the change in dutch roll mode frequency with (i) Increase in vertical tail size (ii) Increase in airplane speed (iii) Increase in yaw moment of inertia (iv) Engines are mounted aft of fuselage. [4]

7. (a) Obtain the transfer function of the system defined by

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}-5 & -1\\ 3 & -1\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}2\\ 5\end{bmatrix}[u]$$

$$y = [1 \quad 2]\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$ [7]

(b) Simplify the block diagram shown in the Fig.3 and obtain the closed-loop transfer function $\dfrac{C(s)}{R(s)}$ [7]

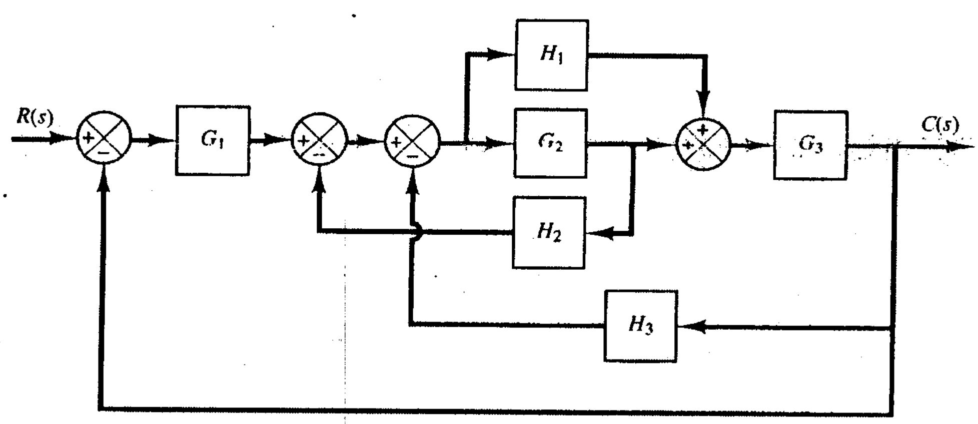

Fig. 3

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8. (a) Find all the time domain specifications for a unit feedback control system whose open loop transfer function is given by [7]

$$G(s)=\frac{25}{s(s+6)}$$

(b) A system is defined by characteristic equation given as

$$s^4+20s^3+224s^2+1240s+2400+k=0$$

(i) Find value of k for which the system will be caused a sustained oscillations. [7]

(ii) Find the frequency of oscillations.