Bengal Engineering and Science University, Shibpur
B.E.(AE) 6th. Semester Final Examination, April, 2013
Sub: Aircraft Stability and Control Sub. Code: **AE604**
Time: 3 hrs. Branch: **Aerospace Engineering and Applied Mechanics**
Answer any **five** questions Full Marks: **70**
Answer in **single** 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

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

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

$$G(s)=\frac{10}{s(1+s)(1+0.02s)}$$

From the Bode plot determine (i) Gain and phase crossover frequencies (ii) Gain and phase margin and (iii) Stability of the closed loop system. [14]

3. (a) The open loop aircraft transfer function for incidence angle feedback to elevator is given by, $\frac{\alpha(s)}{\eta(s)}=\frac{-0.04(s^2-0.0027s+0.0031)(s+203.34)}{(s^2+0.014s+0.0068)(s^2+1.009s+5.56)}$ rad/rad. The corresponding Root Locus plot is shown in Fig. 1. Explain the Root Locus plot and discuss the stability of the aircraft. [7]

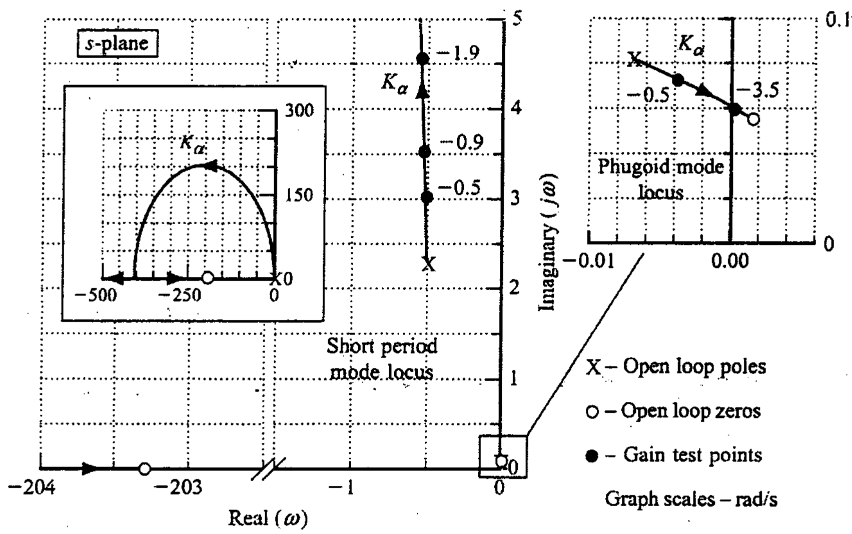

Fig. 1 Root locus plot for incidence feedback to elevator.

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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 it's stability. [7]

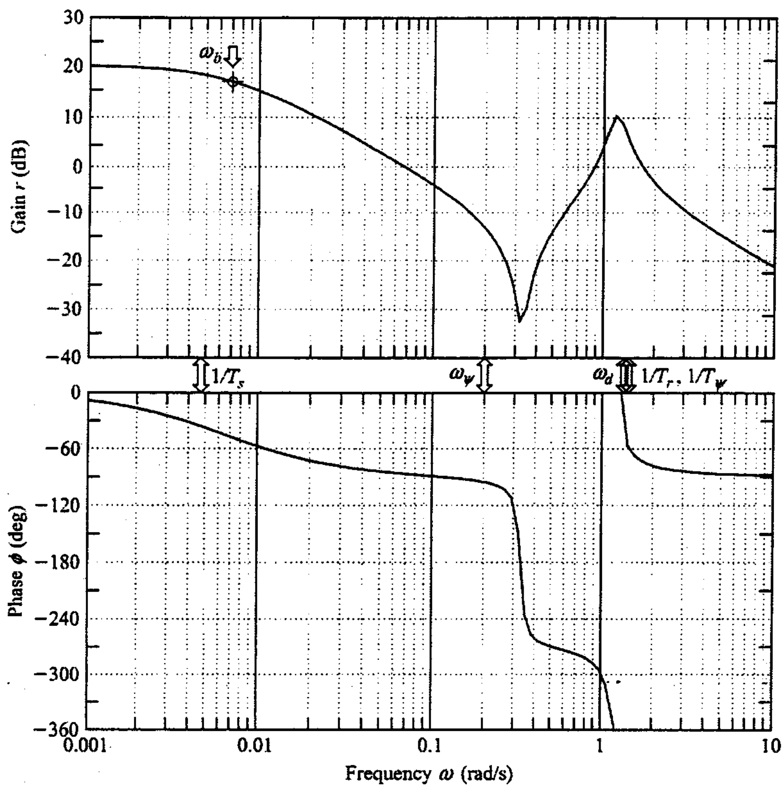

Fig. 2 DC-8 frequency response of yaw rate to rudder.

4. Write short note on any <u>three</u> of the following [14]

(a) Lateral directional flying quality requirements.
(b) Flight control system.
(c) Yaw damper for aircraft stability augmentation.
(d) Short period sensitivity analysis for (i) CG location (ii) Horizontal tail location.
(e) Mason's gain formula for signal flow graph.
(f) Phase Margin for unit feedback control system with O.L.T.F. $G(s) = \dfrac{\omega_n^2}{s(s+2\zeta\omega_n)}$

5. (a) The open loop transfer function of a unit feedback system is given by $G(s) = \dfrac{K}{s(1+sT)}$ [7]

Where T and K are constants and they have positive values. By what factor the amplifier gain needs to be reduced so that (i) Peak overshoot of unit step response of the system is reduced from 75% to 25% (ii) damping ratio is increased from 0.1 to 0.6

(b) Obtain the transfer function $\frac{Y(s)}{X(s)}$ of the system shown in Figure 3. [7]

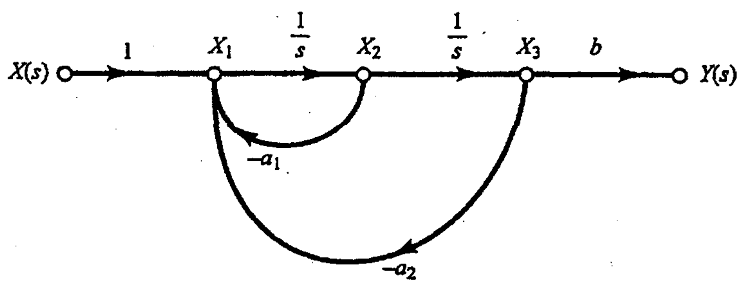

Fig. 3 Signal flow graph of the control system.

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 $\zeta_d = \frac{-\left(N_r + \frac{Y_\beta}{V_{p1}}\right)}{2\omega_{nd}}$ [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) Explain the Routh–Hurwitz stability criterion as it might apply to the following typical aircraft stability quartic,

$As^4 + Bs^3 + Cs^2 + Ds + E = 0$ [7]

What is Routh's discriminant R? Explain the special significance of R and the coefficient E in the context of the lateral–directional stability characteristics of an aircraft.

(b) The coefficients of the above lateral directional stability quartic [Provided in Question 7 (a)] of an aircraft are

$A = 1$, $B = 9.42$, $C = 9.48 + N_v$, $D = 10.29 + 8.4N_v$, $E = 2.24 - 0.39N_v$ [7]

Find the range of values of N_v for which the aircraft will be stable.

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

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ 0 & 0 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

(b) Show that the time period of the longitudinal phugoid mode is approximately expressed by,

$T_{ph} = \frac{(\sqrt{2})\pi V_{p1}}{g}$; where, V_{p1} is true airspeed. State all assumptions used during the derivation. [7]