Indian Institute of Technology, Kharagpur
Department of Aerospace Engineering

Mid-Spring Semester Examination, 2009-10
3rd-Yr B.Tech

Time: 2 h **AE31004 – Aircraft Stability and Control** **Marks: 30**

Aircraft data to be used in Questions 2 & 3

Ambient density at cruising altitude	$1.0\,\mathrm{kg/m^3}$	Cruising speed	40 m/s
mass of aircraft	600 kg	c.g. position (fwd of AC_{WB})	0.15 m
wing area	$12\ \mathrm{m^2}$	horiz. tail area	$2.0\ \mathrm{m^2}$
wing aspect ratio	8.0	non-dim. tail arm	$\bar{l}_T/\bar{c} = 3.0$
wing ref. chord	$\bar{\bar{c}} = 1.22$ m	tail setting angle	8.2°
$\partial C_{L_{WB}}/\partial\alpha$ or a_0	4.8 /rad	$C_{m_{AC(WB)}}$	-0.116
$\partial C_{L_T}/\partial\alpha_T$ or a_1	3.8 /rad	$\partial C_{H_e}/\partial\alpha_T$ or b_1	-0.15 /rad
$\partial C_{L_T}/\partial\eta$ or a_2	1.0 /rad	$\partial C_{H_e}/\partial\eta$ or b_2	-0.18 /rad

Answer all questions. Marks – Q1: 1×9, Q2: 2×2+1+2×3, Q3: 2×3, Q4: 1+1+2

1a) When is an aircraft said to be trimmed for a state of flight?

b) What are the conditions required for an aircraft to be i) longitudinally stable statically, and ii) trimmable at a positive angle of attack?

c) Distinguish between reversible and irreversible controls on an aircraft. What are the advantages and disadvantages of each?

d) What is "stick free" flight of an aircraft that has reversible controls? How do the control surfaces behave in this flight condition? Why is a large stick free static margin undesirable?

e) A $\frac{1}{20}$th scale model of an aircraft flies at $\frac{1}{5}$th the speed of the original aircraft. What fraction of the original elevator hinge moment is developed in the model?

f) Two similar aircraft have wing spans as 1:10 and moments of inertia about the roll axis as 1:8000. How do the times to halve their rates of roll compare?

g) A small, hand launched, glider can fly steadily at a speed of 1.7 m/s. When launched significantly faster than this, however, it zooms rapidly upward. Why?

h) The pilot of an aircraft, flying straight and level at a constant speed somewhat greater than the speed for minimum drag, suddenly applies a small but constant up elevator. Describe the subsequent motion of the centre of mass of the aircraft.

i) What is the function of the dihedral angle in an aircraft? What other design features of an aircraft have effects similar to that of the dihedral angle?

2a) Obtain the pitching moment coefficient of an aircraft about its centre of mass in terms of the lift and moment coefficients of its components.

b) Hence obtain expressions for i) the neutral point of the aircraft with elevator fixed, ii) the pitching moment coefficient about the centre of gravity in terms of the static margin with elevator fixed, and iii) the change in elevator deflection required for a given fractional change in air speed.

c) When the given aircraft (whose data appears in the above table) is in straight and level flight at the conditions given in the table, determine the values of i) C_L and ii) $C_{M_{CG}}$ at which the aircraft is operating.

d) Determine the position, in terms of $\bar{\bar{c}}$, behind the aerodynamic centre of the wing-fuselage combination where the neutral point with elevator fixed of the given aircraft is located.

e) What elevator deflection is needed to maintain the state of flight given in the table?

f) Through what angle must the elevator be moved to obtain an increase in airspeed of 5 m/s?

3a) Obtain an expression for the static margin of an aircraft with elevator free. How much is the static margin of the given aircraft with the elevator free?

b) Assuming that it has no trim tab, obtain an algebraic expression for the floating angle of the elevator in terms of the static margin with elevator free.

c) If the pilot frees the elevator, determine i) the new cruising speed of the aircraft, and ii) the floating angle of the elevator.

4a) An aircraft of mass 360,000 kg, while cruising at 240 m/s TAS, is hit by a gust that imparts to it a vertical impulse of magnitude 4.16×10^6 N-s. Determine the time period, wave length and amplitude of the resulting phugoid oscillation. Assume that the oscillation is undamped.

b) How does the actual phugoid oscillation differ from the idealised model assumed above? Try to write down the *form* of the ordinary differential equation that describes how the altitude varies with time in an actual phugoid oscillation.

c) A model aircraft is mounted in a wind tunnel on a pivot such that it is free to pitch. In a free stream of speed 15 m/s, free pitching oscillations of the model are found to have a time period of 0.98 s and a time to halve amplitude of 3.6 s. Write down the differential equation describing this oscillation.

Which aircraft component, do you think, is mostly responsible for the decay in amplitude? How?