Indian Institute of Engineering Science and Technology, Shibpur
B. E. (Aero.) Part-II 4th Semester Final Examination, 2014
Fundamentals of Aerospace Engineering (AE 406)

Time: 3 Hrs. Full Marks: 70

No SEPARATE Answer scripts are necessary for answering different groups

Group A
Answer any **TWO** of the following questions

1. a) Show that the ratio of static pressure at sonic condition to total pressure at a point in a compressible flow of air is 0.528. 4

   b) Derive the expression of characteristic Mach number. 5

   c) Show that total enthalpy is constant for a steady adiabatic inviscid compressible flow without any body-force. 5

2. a) Derive the expression for thrust of a turbojet engine. 7

   b) Discuss on how thrust of a turbojet engine varies with velocity. 7

3. a) Derive the expression for drag polar. 5

   b) Consider a straight wing with an NACA 2412 airfoil. Assuming low-speed flow, compare the lift coefficients at an angle of attack of 6^0 of the wings if one is with aspect ratio 6 and the other is with 2. Assume span efficiency factor 0.95. **Use fig. Q. 3 (b) for airfoil data.** 9

Group B
Answer any **TWO** of the following questions

4. a) Explain why elevator is required for longitudinal static control of an aircraft. 2

   b) The pitching moment coefficient curve from wing body tail combination of an airplane is given by the expression

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$C_{M,cg} = C_{M,ac_{wb}} + C_{L_{wb}}(h - h_{ac_{wb}}) - V_H C_{L,t}$, where the symbols have their usual meanings. Find the expression of $C_{M,cg}$ considering the effect of elevator deflection and derive the expression for elevator angle to trim. 5

c) Explain the elevator position in (i) low flight velocity (ii) high flight velocity 3

d) The NACA 64-412 airplane has an elevator added to the horizontal tail. The elevator control effectiveness $\left(\frac{\partial C_{L,t}}{\partial \delta_e}\right)$ is 0.04. Pitching moment coefficient at zero angle of attack ($C_{M,0}$) is 0.139. Slope of C_m vs α_a curve $\left(\frac{\partial C_{M,cg}}{\partial \alpha_a}\right)$ is given as -0.04 and tail volume ratio (V_H) is 0.5926. Calculate the elevator deflection angle necessary to trim the airplane at an angle of attack of 8^0. 4

5. a) What do you understand by stick-free and stick-fixed longitudinal stability. 2

b) Why stick-free static margin is smaller than stick-fixed static margin. Explain with deriving necessary expression considering free elevator deflection. 6

c) The NACA 64-412 airplane has elevator control effectiveness $\left(\frac{\partial C_{L,t}}{\partial \delta_e}\right)$ is 0.04, lift slope of the tail (a_t) is 0.12 per degree, tail volume ratio (V_H) is 0.5926, tail setting angle (i_t) is 2^0, downwash angle when wing-body combination is at zero life (ε_0) is zero, $\frac{\partial \varepsilon}{\partial \alpha}$ is 0.42, lift slope of the wing body (a) is 0.09, location of aerodynamic center/chord length $(h_{ac,wb})$ is 0.24, location of center of gravity/chord length (h) is 0.26, the elevator hinge moment derivatives are $\left(\frac{\partial C_{he}}{\partial \alpha_t}\right)$ is -0.007, $\left(\frac{\partial C_{h_e}}{\partial \delta_e}\right)$ is -0.012. Assess the stick-free static margin of this configuration and compare it with stick-fixed static margin of the airplane. 6

6. a) State the static stability criteria for directional stability of an airplane. 2

b) Derive the expression of airplane yaw moment coefficient (C_n) for contribution of vertical tail on directional stability of an aircraft. Express in terms of vertical tail volume ratio, ratio of dynamic pressures at vertical tail and wing, side wash angle, side slip angle and $C_{L\alpha v}$. 4

c) State the static stability criteria for roll stability of an airplane. 2

d) Draw suitable velocity triangle of airplane dihedral wings and explain how rolling moment brings the wing back to wings-level attitude. 3

e) Discuss on the contribution of wing sweep, fuselage, horizontal tail and vertical tail on roll stability of an aircraft. 3

Group C

Answer any **ONE** of the following questions

7. a) Write down the expressions for calculating stiffness of axial, bending and torsion member. You can assume the parameters required as per your convenience. 3

b) Why bending stress is more dominant than shear stress for commercial aircraft wing? 3

c) Which are the factors should be considered in selection of an aircraft material? 3

d) Write short notes on fuselage, spar, rib, skin and lug . 5

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8. a) What is fatigue? 2

b) Why a material fails below the yield stress during a cyclic loading? 3

c) What are the factors affecting fatigue life of a material? 4

d) What is Palmgren-Miner Cumulative Damage rule? 2

e) A steel component is subjected to a reversed cyclic loading of 100 cycles/day over a period of time in which $\pm$ 160 N/mm^2 is applied for 200 cycles, $\pm$ 140 N/mm^2 is applied for 200 cycles and $\pm$ 100 N/mm^2 is applied for 600 cycles. If the fatigue life of the material at each of these stress levels is 10^4, 10^5 and 2×10^5 cycles, respectively estimate the life of the component using Miner's law. 3

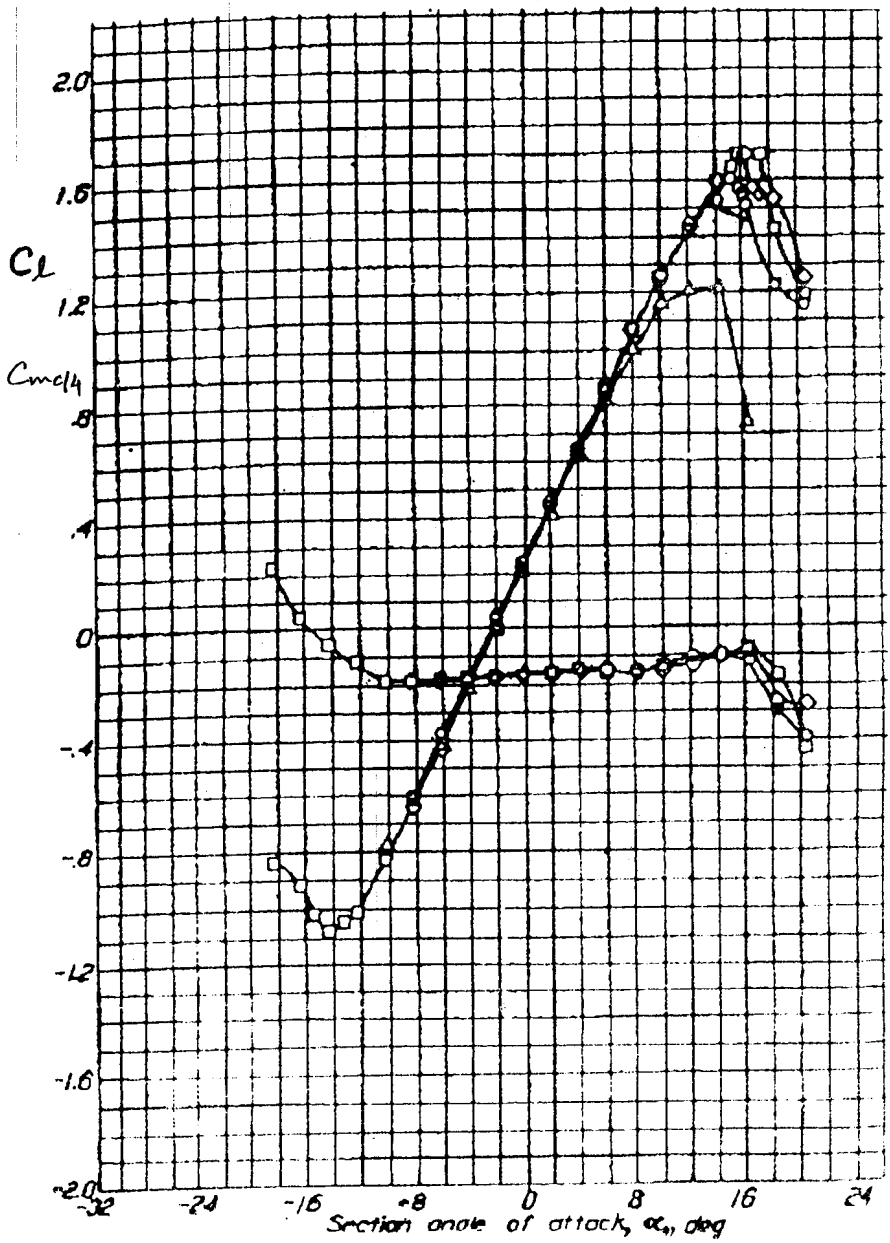
2.0
1.6
C_l
1.2
$C_{m_{c/4}}$
.8
.4
0
-.4
-.8
-1.2
-1.6
-2.0
-32
-24
-16
-8
0
8
16
24
Section angle of attack, α_n, deg

Fig. Q. 3 (b)