B. E. (Aero.) Part-II 4th Semester Final Examination, 2012

Introduction to Aerospace Engineering (AE 405)

Time: 3 Hrs. Full Marks: 70

Answer any five of the following questions

1. a) Derive the expression of Lift coefficient from the surface pressure distribution on an airfoil at low angle of attack. (7)

b) Consider an airfoil with chord length *c* and the running distance *x* measured along the chord. The leading edge is located at $x/c = 0$ and the trailing edge at $x/c = 1$. The pressure coefficient variation over the upper and lower surfaces are given, respectively, as

$C_{p,u} = 1 - 300\,(x/c)^2$ for $0 \leq x/c \leq 0.1$

$C_{p,u} = -2.2277 + 2.2277\,(x/c)$ for $0.1 \leq x/c \leq 1.0$

$C_{p,l} = 1 - 0.95(x/c)$ for $0 \leq x/c \leq 1.0$

Calculate the normal force coefficient. (7)

2. a) A supersonic nozzle is fed by a large reservoir at the inlet of the nozzle. In the reservoir of the nozzle, the pressure and temperature are 10 atm and 300 K, respectively. At the nozzle exit the pressure is 1 atm. Calculate the temperature and density of the flow at the exit. Assume an isentropic and compressible flow. (5)

b) In a low speed subsonic wind-tunnel, one side of the mercury manometer is connected to the settling chamber (reservoir) and the other side is connected to the test section. The contraction ratio between the cross sections of test section to that of settling chamber is 1:15. The reservoir pressure and temperature are 1.1 atm and 300 K respectively. When the tunnel is running the difference of mercury column heights is 10 cm. The density of liquid mercury is 1.36×10^4 kg/m^3. Calculate the air flow velocity and Mach number in the test section. Assume density of air at this speed is constant. (5)

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c) A Pitot tube is inserted into an airflow where the static pressure is 1 atm. Calculate the flow Mach number when the Pitot tube measures 1.276 atm. (4)

3. (a) Define the criteria for longitudinal static stability of the airplane. For a positively cambered wing explain the effect of various design parameters of the airplane on its longitudinal static stability. (6)

   (b) A wing-body model is tested in a subsonic wind tunnel. The lift is found to be zero at geometric angle of attack $\alpha = -1.5^0$. At $\alpha = 5.5^0$, the lift coefficient is measured as 0.54. Also, at $\alpha = 1^0$ and $\alpha = 7.88^0$, the pitching moment coefficients about the center of gravity are measured as 0.01 and 0.05, respectively. The center of gravity is located at $0.35c$. Here, c is the mean zero lift chord of the wing. Calculate the location of aerodynamic center and value of moment coefficient about aerodynamic center $C_{M,ac_{wb}}$. (8)

4. (a) For static longitudinal control of airplane, derive the expression for elevator angle of deflection to trim the airplane. (6)

   (b) Explain stick-fixed and stick-free longitudinal static stability of an airplane. Why stick-free static margin is smaller than stick-fixed static margin. Explain with deriving necessary expression considering free elevator deflection. (8)

5. (a) Explain (i) hysteresis loop in strain hardening (ii) creep rate (iii) Miner's cumulative damage equation and its applicability. (9)

   (b) Discuss in brief, the principal aerodynamic forces appearing on a generic airplane during flight, with suitable schematic diagram(s). (5)

6. Show the major components of a generic aircraft in a typical sub-assembly breakdown sketch. Discuss the components in brief. (5 + 9)

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7. a) Consider a propeller advancing into still air at steady speed V_∞. Assuming one-dimensional idealized flow, show that half the velocity rise occurs upstream and half downstream of the propeller disk. State all the necessary assumptions. (7+2)

   b) Draw the variation of propeller efficiency with the advance ratio for a given pitch angle. What are the advantages of a variable-pitch propeller over a fixed-pitch propeller? (2+3)

8. a) Describe briefly the four-stroke cycle of a spark ignition reciprocating engine. Draw the associated thermodynamic cycle using a p-V diagram and indicate each process in the figure. (6+2)

   b) Consider a turbojet powered airplane flying at an altitude of 9000 m at a velocity of 800 km/h. The turbojet engine itself has inlet and exit areas 0.95 m^2 and 0.8 m^2, respectively. The velocity and pressure of the exhaust gas at the exit are 500 m/s and 3.2 □ 10^4 N/m^2, respectively. Calculate the thrust of the turbojet. Assume linear temperature variation with altitude (z), i.e. $T = T_0 - mz$, where m = 6.5°C/km, atmospheric temperature and pressure at sea-level are 15°C and 101 kPa, respectively. Take $R = 287\ \mathrm{J \cdot kg^{-1} \cdot K^{-1}}$ for air. (6)