B.E. Mechanical Engineering - Third Year - Second Semester, (Suppl.) 2023

SUBJECT: Aerodynamics

Time: Three hours | Full Marks 100

[Answer any 5 (five)]

Q1. Justify:

a. In a 2D analysis of aerofoil with infinite span hypothesis, no induced drag can be generated.

b. Spiral staircases are used surrounding long chimneys.

c. Two high speed vehicles moving side by side tend to attract one another. [6+7+7]

Q2. a. Consider an infinitely thin plate of 1 m chord at an angle of attack of 10 degree in a supersonic flow. The pressure and shear stress distribution of upper and lower surfaces respectively are:

$p_u = 4 \times 10^4 (x-1)^{0.2} + 5.4 \times 10^4$

$p_l = 2 \times 10^4 (x-1)^{0.2} + 1.7 \times 10^5$

$\tau_u = 288x^{-0.2}$

$\tau_l = 731x^{-0.2}$

where x is the distance from the leading edge in meter and p and τ are in N/m^2. Calculate the lift and drag, moment about the quarter chord point, all per unit span. Locate the centre of pressure.

b. Explain the nomenclature NACA2412.

c. What do you mean by canard configuration? Why is it used? Comment on the disadvantages of the same. [8+5+7]

Q3. a. Consider two different flows over geometrically similar aerofoil shapes, one aerofoil being twice in size of the other. The flow over the smaller aerofoil has freestream properties: T_∞ = 200K, ρ_∞=1.23kg/cu.m, V_∞=100m/s. The flow over the smaller aerofoil has freestream properties: T_∞ = 800K, ρ_∞=1.739kg/cu.m, V_∞=200m/s. If μ and a are proportional to $T^{0.5}$, are these flows dynamically similar?

b. Explain the working principle of a supersonic pitot tube. [10+10]

Q4. Write short note on

a. Starting Vortex and Kutta Condition

b. DRS for high speed vehicles

c. Strouhal Number

d. Mean Camber line [5x4]

Q5. a. Explain with neat figures two necessary criteria for longitudinal static stability of an airplane.

b. Consider a propeller-driven, single-engine, light airplane weighting 1400kg and wing reference area of 16 sq mt. Consider $C_D=0.025+0.054C_L^2$

For steady level flight at sea level, where the density of air is 1.293 kg/cu.m., plot C_D, C_L and L/D for flight velocity ranging between 20m/s to 60m/s. [10+10]

Q6. a. Consider a model of wing-body shape mounted in a wind tunnel. The flow conditions in the test section are standard sea level properties with a velocity of 100m/s. The wing area and chord are 1.5 sqm and 0.45m respectively. The zero lift moment about centre of gravity is found to be - 12.4Nm. When the model is pitched to another angle of attack, the lift and moment about CG are measured to be 3675N and 20.67Nm respectively. Find the location of aerodynamic centre and calculate the moment co-efficient about the same.

b. If a mass is added in a way that the CG is shifted rearwards by 0.2c, calculate the moment about CG when the lift is 4000N.

c. Assume a horizontal tail with no elevator is added to this model. The distance of the tail's aerodynamic centre from the CG of the airplane model is 1.0m. The area of the tail is 0.4 sqm, the tail setting angle being 2 degree. The lift slope of the tail is 0.12 per degree. From experimental measurements, α_a = 5degree, ε_0 = 0.01 and $\delta\varepsilon/\delta\alpha$ = 0.42. If the lift at absolute angle of attack if 4134N, calculate the moment about CG. Does this model have longitudinal static stability and balance? [20]