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

SUBJECT: Aerodynamics

Time: Three hours Full Marks 100

[Answer Question No. 1 and any 5 (five) from the rest]

Q1. Explain the aerodynamics behind the followings:
a. Free kicks taken a footballer can bend in the air to reach the goal.
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 a propeller-driven, single-engine, light airplane weighting 1400kg and wing reference area of 16 sq mt. Consider C_D=0.025+0.054$C_L{}^2$
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.
b. What do you mean by 'Mean Camber line' of an aerofoil.
c. Explain the nomenclature NACA2412. [8+3+5]

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. [8+8]

Q4. a. What frequency of oscillation is expected when air of kinematic viscosity 15 sqmm/s flows at 25m/s past a 4 mm diameter telephone wire which is perpendicular to the air stream.
b. Write short note on: i. Starting Vortex and Kutta Condition, ii. DRS for high speed vehicles [4+(6+6)]

Q5. a. For a given wing body combination, the aerodynamic centre lies at 0.35c ahead of the CG. The moment co-efficient about CG is 0.0050 while the lift co-efficient is 0.50. Calculate the moment co-efficient about the aerodynamic centre.
b. What do you mean by canard configuration? Why is it used? Comment on the disadvantages of the same.
c. Can Induced Drag occur in 2D aerofoil? Justify. [4+6+6]

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, $\alpha_a = 5$degree, $\varepsilon_0 = 0.01$ 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? [4+4+8]

Q7. a. Explain with neat figures two necessary criteria for longitudinal static stability of an airplane.

b. 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. [8+8]