INDIAN INSTITUE OF TECHNOLOGY, KHARAGPUR

Date of exam. : 17-04-2013 Time: 3 Hrs Full marks: 50 No. of Students : 52

Spring End-Sem: 2012-13 Dept of Aerospace Engineering 2nd Yr. B.Tech (Hons.)

Sub. No: AE21002 Subject Name: Low Speed Aerodynamics

Instructions: Answer ALL Five Questions. Marks are indicated

Q-1 Two identical aeroplanes, having elliptic wings, are flying side by side and always maintaining a horizontal distance h=2xspan while flying horizontally. Each one is of weight W and flying horizontally with same speed V. Estimate the change in induced drag due to interference effects. If W=18x10^4 N, s=12.5 m, $\rho = 1.216$ and v=50 m/s, calculate the % change in the induced drag.

(Marks=10)

Q-2 For a wing of semi-span s, the span-wise wing loading is approximated by constant value Γ_0 from $y = -\frac{4}{5}s$ to $y = +\frac{4}{5}s$ and beyond these span-wise locations the loading varies linearly from Γ_0 to zero at the respective wing tips.

(a) Sketch the wing loading and associated trailing vortex system of the wing indicating clearly the direction and magnitude of the trailing vortices.

(b) The vortex system of this wing is replaced by a simplified model represented with a single horse-shoe vortex, find the relation between downwash velocities induced at the mid-span by the original wing loading and its simplified equivalent case if (i) Each must provide the same total lift and (ii) Each must have the same wing span.

(Marks=3+7)

Q-3 A straight wing of symmetrical cross-section is twisted such that when the incidence at the mid span is 2^0 the circulation Γ at a span wise distance y from the wing root is given by

$$\Gamma = \Gamma_0[1+\frac{y^2}{s^2}]\sqrt{1-\frac{y^2}{s^2}}$$

(a) Find a general expression (as function of y/s) for the downwash velocity along the span and

(b) Also determine the corresponding incidence at the wing tips.

The wing has aspect ratio of 8.0 and the taper ratio of 0.4. You may use the lift curve slope for two-dimensional flow as 5.8. **(Marks=5+5)**

Q-4 (a) Velocity potential (total) at any field point P is given by green's identity as

$$\phi_P = \phi_{\infty_P} + \int_S [(\hat{n}\bullet\nabla\phi)\phi_s - (\phi)\hat{n}\bullet\nabla\phi_s]ds$$

where $S=S_B+S_C$.

Starting with this equation describe in detail the potential (doublet) based panel method.

(b) Modify the above panel method if one wishes to work with perturbation velocity potential instead of total velocity potential as in part (a). **(Marks= 7+3)**

Q-5 **(a)** With the help of examples, explain simply and doubly connected regions.

(b) Show that in a simply connected region, irrotational flow is characterized by a single valued velocity potential where as for doubly connected region it is not true.

(c) Explain how a doubly connected region can be reduced to a simply connected region?

(d) Show that in the doubly connected region circulation about all the circuits enclosing the body is same.

(e) In context with incompressible potential flow past an aerofoil, define the exterior Neumann problem. Also state and prove uniqueness theorem for exterior Neumann problem in doubly connected region

(Marks= 1x4+6)

OR

Q5 (a) Starting with Biot-Savart law show that the magnitude of the velocity induced due to a finite length straight vortex AB of strength Γ at any point P at a distance h from the vortex line is.

$$V = \frac{\Gamma}{4\pi h}(\cos\alpha + \cos\beta)$$, where α & β are the angles at A and B respectively of the triangle ΔABP.

(b) Find the velocity components u, v and w at point P(x, y, z) of this induced velocity where the straight vortex extending from point A(x_1,y_1) to point B (x_2,y_2). **(Marks=5+5)**