Exam Date & Time: 07-May-2024 (02:30 PM - 05:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

FOURTH SEMESTER B.TECH END SEMESTER EXAMINATIONS, MAY 2024

INCOMPRESSIBLE AERODYNAMICS [AAE 2221]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions. Section Duration: 180 mins

Instructions to Candidates: Answer ALL questions Missing data may be suitably assumed

1) Briefly describe the center of pressure and the aerodynamic center of an airfoil. Consider a NACA 2412 airfoil. The following is a tabulation of the lift, drag, and moment coefficients about the quarter chord for the airfoil, as a function of the angle of attack.

A) Calculate the variation of the center of pressure for each angle of attack and plot the same. (5)

α (degree)	c_l	c_d	$c_{m,c/4}$
-2	0.05	0.006	-0.042
0	0.25	0.006	-0.040
4	0.64	0.007	-0.036
8	1.08	0.0092	-0.034

B) Sketch the flow patterns surrounding a circular cylinder in both inviscid and viscous flows and explain the rationale behind the observed flow patterns. (3)

C) Examine the importance of the substantial derivative in the context of 'incompressible aerodynamics'. (2)

2) Consider a flow due to a vortex of strength Γ at the origin. Evaluate the circulation about a clockwise path from (a,0) to (2a,0) to (2a, -a) and (a, -a). Interpret your result. (2)

A)

B) When a circulation of strength Γ is imposed on a cylinder placed in a uniform incompressible flow of velocity V_∞, the cylinder experiences lift. If the lift coefficient (3)

$C_L = 2$, calculate the peak (negative) pressure coefficient on the cylinder.

C) When a circulation of strength Γ is imposed on a cylinder placed in a uniform incompressible flow off velocity V_∞, the cylinder experiences lift. If the lift coefficient $C_L = 2$, calculate the stagnation points on the cylinder and the locations where static pressure is equal to free stream pressure. (5)

3) A) Consider an NACA 23012 airfoil. The mean camber line for this airfoil is given by

$z/c = 3.2\ [\ (x/c)^3 - 0.8\ (x/c)^2 + 0.11\ (x/c)]$ for $0 \leq x/c \leq 0.4$ &

$z/c = 0.2\ [\ 1- (x/c)^3\ ]$ for $0.4 \leq x/c \leq 1.0$

Calculate (a) the angle of attack at zero lift, (b) the lift coefficient when $\alpha = 5^o$, (c) the moment coefficient about the quarter chord, and (d) the location of the center of pressure in terms of x_{cp}/c, when $\alpha = 5^o$. (5)

B) Describe the concept of formation flying and explain why it is used in aircraft by comparing it to how birds often fly together. (3)

C) Provide a detailed explanation on the ground effect phenomenon. (2)

4) State Kelvin's circulation theorem and its application in interpreting the generation of circulation around an airfoil. (5)

A)

B) Explain briefly on the Source and Vortex panel methods. (3)

C) The measured lift slope for the NACA 23012 airfoil is 0.1080 degree^{-1} and $\alpha_{L=0} = -1.3^o$. Consider a finite wing using the airfoil, with AR = 8 and taper ratio = 0.8. Assume that $\delta=\tau$. Calculate the lift and induced drag coefficients for this wing at a geometric angle of attack of 7^o. (2)

5) Prove that elliptical wings represent the optimal wing planform for a finite wing in terms of lift, downwash, and induced drag. (4)

A)

B) Distinguish between the lift curve of a wing and that of an airfoil. Provide a derivation for the slope of a lift curve in a generic wing. (3)

C) Discuss the impact of aspect ratio on aircraft lift and induced drag. Illustrate using a few examples of aircraft in the subsonic, transonic, and supersonic flow regimes. (3)

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