Roll No: --------------------------

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2017

Program: B. Tech. ASE and B. Tech. ASE+AVE **Semester – V**
Subject (Course): Aerodynamics II **Max. Marks : 100**
Course Code : ASEG 311 **Duration : 3 Hrs**
No. of page/s: 03

Assume missing data, if any, appropriately. Use sketches to justify your answer wherever required.

Section A

Section A has five (05) questions of 04 marks each. These questions are of short answer type (maximum of 60 words) and all the questions in this section are compulsory.

1. Explain the Joukowski hypothesis for the ammount of circulation produced by an airfoil.
2. If the local circulation at 30% chord of a flat plate in a flow at 40 m/s is 24 m^2/s, determine the angle of attack.
3. A wing with an elliptical planform and an elliptical lift distribution has aspect ratio 6 and span of 12 m. The wing loading is 900 N/m^2, when flying at a speed of 150 km/hr at sea level. Calculate the induced drag for this wing.
4. At a given point on the surface of an airfoil, the pressure coefficient is -0.3 at very low speeds. Calculate the pressure coefficient at this point when the freestream Mach number is 0.6.
5. Why is elliptic lift distribution desirable for wings of finite aspect ratio? Discuss the use of aerodynamic twist and geometric twist for obtaining the desired lift distribution.

Section B

Section B has four (4) questions of 10 marks each. These questions are of long answer type (maximum 200 words for each question). All questions in this section are compulsory.

6. Transform the uniform flow parallel to x-axis of the physical plane, with the transformation function $\zeta = z^2$.

7. A thin airfoil has a circular-arc camber line with a maximum of 0.025 chord. Determine the theoretical pitching moment coefficient $C_{M1/4}$. The camber line may be approximated by the expression

$$z = kc\left[\frac{1}{4} - \left(\frac{x'}{c}\right)^2\right]$$

where $x' = x - 0.5c$

8. State Helmholtz's laws for vortex motion. Consider a square ring vortex of side 2a. If each side has strength Γ, calculate the velocity induced at the center of the ring.
9. The spanwise distribution of circulation along an untwisted rectangular wing of aspect ratio 5 can be written in the form:

$$\Gamma = 4sV\alpha[0.02340\ \sin\theta + 0.00268\ \sin 3\theta + 0.00072\ \sin 5\theta + 0.00010\ \sin 7\theta]$$

Calculate the lift and induced drag coefficients when the incidence α measured to no lift is 10˚.

Section C

Section C has three (03) questions of 20 marks each. Question number 10 is compulsory. Answer any one question from 11 and 12. These questions are of long answer type (maximum 500 words for each question).

10. (a) Show that for small perturbations, the linearized pressure coefficient can be given by

$$C_p = -\frac{2\hat{u}}{V_\infty}$$

where $\hat{u}$ is the perturbation in the *x*-component of the freestream velocity, and V_∞ is the freestream velocity.

(b) Define Critical Mach number and discuss the effect of airfoil thickness and wing sweepback on the value of the critical Mach number an airfoil. Use appropriate sketch to justify your answer.

11. An aeroplane weighing 250 kN has a span of 34 m and is flying at 40 m/s with its tailplane level with its wings and at height 6.1 m above the ground. Estimate the change due to ground effect in the downwash angle at the tailplane, which is 18.3 m behind the centre of pressure of the wing.

12. A wing of symmetrical cross-section has an elliptical planform and is twisted so that when the incidence at the centre of the span is 2° the circulation Γ at a distance y from the wing root is given by

$$\Gamma = \Gamma_0 \left[1 - \left({}^{y}/_{s}\right)^2\right]^{3/2}$$

Find a general expression for the downwash velocity along the span and determine the corresponding incidence at the wing tips. The aspect ratio is 7.0 and the lift-curve slope for the aerofoil section in two-dimensional flow is 5.8.

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Section A

Section A has five (05) questions of 4 marks each. These questions are of short answer type (maximum of 60 words) and all the questions in this section are compulsory.

1. Define *wash in* and *wash out*. How can a wing be aerodynamically twisted? Explain briefly.
2. Discuss the Kutta's condition for the magnitude and direction of velocity at the trailing of an airfoil.
3. At a given point on the surface of an airfoil, the pressure coefficient is -0.54 at very low speeds. Calculate the pressure coefficient at this point when the freestream Mach number is 0.58.
4. A flat plate is at an incidence of 2° in a flow; determine the location of centre of pressure.
5. A monoplane weighing 73575 N has elliptic wing of span 15 m. When it flies at 300 km/h at sea level, determine the circulation around a section halfway between the wing root and the wing tip.

Section B

Section B has four (4) questions of 10 marks each. These questions are of long answer type (maximum 200 words for each question). All questions in this section are compulsory.

6. State Helmholtz's first and second laws for vortex motion. Show that a circular vortex ring of intensity Γ induces an axial velocity $\Gamma/2R$ at the center of the ring, where R is the radius of the vortex.

7. In thin airfoil theory, airfoils are replaced by vortex sheet superimposed on the camber line. If a flat plate is placed a uniform stream at an angle of attack α find an expression for the local strength of the vortex sheet. Assume that the amount of circulation produced around the airfoil is such that it satisfies the Kutta's condition.
8. Transform a circle of radius a with the centre in the z-plane located on the x-axis, to a symmetrical aerofoil using Kutta–Joukowski transformation function:

$$\zeta = z + \frac{b^2}{z}$$

   Also, find an expression for the thickness to chord ratio of the transformed airfoil.
9. A rectangular, untwisted, wing of aspect ratio 3 has an aerofoil section for which the lift-curve slope is 6.0 in two-dimensional flow. Take the distribution of circulation across the span of a wing to be given by

$$\Gamma = 4sV \sum A_n \sin n\theta$$

   and use the general theory for wings of high aspect ratio to determine the approximate circulation distribution in terms of angle of incidence by retaining only two terms in the above expression for circulation and satisfying the equation at $\theta = \pi/4$ and $\theta = \pi/2$.

Section C

Section C has three (03) questions of 20 marks each. Question number 10 is compulsory. Answer any one question from 11 and 12. These questions are of long answer type (maximum 500 words for each question).

10. (a) Derive an expression for the linearized pressure coefficient in compressible subsonic flow with small perturbation velocities.

    (b) Define Critical Mach number and discuss the effect of airfoil thickness and wing sweepback on the value of the critical Mach number an airfoil. Use appropriate sketch to justify your answer.
11. An aeroplane weighing l00 kN has a span of 19.5m and a wing-loading of 1.925 kN/m. The wings are rather sharply tapered, having around the centre of span a circulation 10% greater than that for elliptic wings of the same span and lift. Determine the downwash angle one-quarter of the span behind the centre of pressure, which is located at the quarter-chord point. The air speed is 67 m/s. Assume the trailing vorticity to be completely rolled up just behind the wings.

12. For a wing with modified elliptic loading such that at distance *y* from the centre of the span, the circulation is given by

$$\Gamma = \Gamma_o \left(1 + \frac{1}{6}\frac{y^2}{s^2}\right)\sqrt{1 - \frac{y^2}{s^2}}$$

where *s* is the semi-span, show from first principle that the downward induced velocity at *y* is

$$\frac{\Gamma_0}{4s}\left(\frac{11}{12} + \frac{y^2}{2s^2}\right)$$

Also, prove that for such a wing of aspect ratio (A_R) the induced drag coefficient at lift coefficient C_L is

$$C_{D_i} = \frac{628}{625}\frac{C_L^2}{A_R}$$