UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 8 Examination in Engineering: December 2015

Module Number: ME 8336 **Module Name: Aerospace Engineering**

[Three Hours]

[Answer **all questions**, each question carries **twelve** marks]

NOTES:

Use carefully labelled sketches to support your answers where necessary.
You may make additional assumptions, but clearly state them in your answers.
Data and formulae are given in page 4.

Q1. a) On a schematic diagram, show all the key control surfaces of an aircraft. Also briefly describe the function of each of them.

[2.0 Marks]

b) Define the terms "absolute height" and "geopotential height".

[2.0 Marks]

c) Comment on the statement: "Boundary layer development over the fuselage does not affect the accurate static pressure measurements in an aircraft."

[2.0 Marks]

d) During a cruising phase of an aircraft, it was recorded that the air speed indicator reading (ASIR) as 187 knots. As a result of errors in pressure measurements, it was found that static pressure error was -210 Pa. If the instrument error correction for the air speed indicator (ASI) is +0.8 knots, estimate the pressure error correction for the ASI, assuming that the pitot pressure error is zero.

[6.0 Marks]

Q2. a) Describe stalling patterns for a rectangular wing, a tapered wing, and an elliptic wing.

[2.0 Marks]

b) What is your recommendations for optimum taper ratio and position of the control surfaces in relation to a tapered wing? Justify your answer.

[3.0 Marks]

c) Explain the statement: "Increasing in the aspect ratio is not a viable solution to minimize the drag acted on passenger transport aircraft."

[3.0 Marks]

d) An elliptic lift distribution pattern is given with usual notations by;

$$L'(y) = \rho_\infty V_\infty \Gamma_0 \sqrt{1-\left(\frac{2y}{b}\right)^2}$$

Hence show that, for a wing having elliptic planform shape has a constant local lift coefficient throughout its span.

[4.0 Marks]

Q3. a) Draw the variation of lift coefficient with respect to angle of attack for the following airfoil shapes.

i. NACA 0016

ii. NACA 5400

[2.0 Marks]

b) Explain the statement, "Even though airfoil is a streamline body, the flow trends to separate towards the trailing edge (TE) of the airfoil".

[3.0 Marks]

c) Consider an airfoil with chord length c and the running distance x measured along the chord. The leading edge is located at $x/c=0$ and the trailing edge at $x/c=1$. The pressure coefficient variations over upper and lower surfaces are given by following three expressions:

$$C_{P1}=1-300\left(\frac{x}{c}\right)^2 \text{ for } 0\le x/c\le 0.1,$$

$$C_{P2}=-2.2277+2.2277\left(\frac{x}{c}\right)^2 \text{ for } 0.1 < x/c \le 1,$$

$$C_{P3}=1-0.95\left(\frac{x}{c}\right) \text{ for } 0\le x/c\le 1.$$

i. What are the expressions from above that show C_p variations over the upper surface of the airfoil? Justify your answer.

ii. Estimate the lift coefficient of the airfoil.

[7.0 Marks]

Q4. a) Write the most general expression for total drag acted on a finite wing. Also state the main sources of the drag for each term in your expression.

[2.0 Marks]

b) Describe how the wave drag is generated on airfoils.

[2.0 Marks]

c) The wings of an Unmanned Aerial Vehicle (UAV) are made of NACA 23015 airfoil section. The tapered planform wings have a total span of 38 m; while the root chord length and the tip chord length are 6.5 m and 1.7 m, respectively. The UAV cruises with 28 km/h at an altitude of 20 km, where the density and the kinematic viscosity of air are 0.158 kgm^{-3} and 16.312 × 10^{-6} m^2/s, respectively.

The lift coefficient and the drag coefficient variations for the NACA 23015 as a function of AoA are presented in Table Q4 and the efficiency factor for the wing is 0.95. Taking $\tau=0.55$, and if the UAV is at 5° of angle of attack, determine;

i. Reynolds number of the UAV,

ii. Lift and drag coefficient,

iii. The gross mass of the UAV.

[8.0 Marks]

Q5. a) Write key steps in negative rolling of an aircraft. What is the sign of control surface deflection? Justify your answer.

[2.0 Marks]

b) Define the aerodynamic center of an airfoil. Show that for an airfoil, the aerodynamic center is located at 25% of the chord length.

[2.0 Marks]

c) What is the requirement for a statically stable aircraft? Explain your answer.

[2.0 Marks]

d) On a schematic diagram, mark all the forces acted on an aircraft in a pure longitudinal flight and Then derive all the modelling equations. You may take all the relevant angles to be small. Hence,

i. Derive symbolic expressions for the equilibrium angle of attack (α_e),

ii. Obtain expressions for changes in equilibrium angle of attack ($\Delta\alpha_e$) when the pilot has increased the elevator command by an amount of δm.

[6.0 Marks]

Table Q4: NACA 23015 airfoil data

Angle of Attack (AoA) (in degrees)	Lift coefficient - c_ℓ	Drag coefficient - c_d
-4	-0.24	0.008
-2	0.08	0.006
0	0.4	0.006
2	0.72	0.006
4	1.04	0.007
6	1.36	0.0075
8	1.68	0.0092
10	2.00	0.0098

Data & formulae sheet

a.) True air speed of an aircraft is given by:

$$V = \sqrt{\frac{2\gamma}{\gamma - 1}\frac{P_\infty}{\rho_\infty}\left\{\left[1 + \frac{P_T - P_\infty}{P_\infty}\right]^{\frac{\gamma - 1}{\gamma}} - 1\right\}}$$

b.) Airfoil lift curve slope a_0 and 3-D wing lift curve slope a_1 are related as:

$$a_1 = \frac{a_0}{1 + \left(\frac{a_0}{\pi AR}\right)(1 + \tau)}$$

c.) For an airfoil, the lift coefficient is given by:

$$c_\ell = \left[\int_0^1 (C_{p,\ell} - C_{p,u})\, d\left(\frac{x}{c}\right)\right]$$

d.) 1 knot = 0.5144 ms^{-1}.