UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 8 Examination in Engineering: November 2016

Module Number: ME8311 **Module Name: Aerospace Engineering**

[Three Hours]

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

NOTES:

- Use carefully labeled sketches to support your answers where necessary.
- You may make additional assumptions, but clearly state them in your answers.
- Data and formulae are given from page 4 to page 6.

Q1. a) Differentiate between the geometric height and the geopotential height. Does the use of geopotential height in commercial aircraft compromise its safety?

[2.0 Marks]

b) A passenger transport aircraft cruises with 850 km/h at a pressure altitude of 9.8 km. Estimate the reading of the pitot pressure probe of the aircraft.

[3.0 Marks]

c) Explain why the indicated pressure altitude is not necessarily equal to the calibrated pressure altitude.

[2.0 Marks]

d) On a medium size aircraft, an altimeter reading of 5100 m was recorded. It is given that the altimeter instrument error and the static pressure error correction are +11.2 m and +24.1 m, respectively. Determine the static pressure error.

[5.0 Marks]

Q2. a) Plot the variation of lift coefficient and the moment coefficient with angle of attack for the following cases:

i) Cambered airfoil,

ii) Symmetric airfoil.

[1.0 Mark]

b) Describe the functions of flaps, slats and spoiler of an aircraft.

[4.0 Marks]

c) Table Q2 summarizes pressure distribution data for flow over CY-14 airfoil, which were obtained from the Educational Wind Tunnel (EWT) when it is operating at 20.1 ms^{-1}. The test has been conducted at a pressure of 100125 Pa and a temperature of 28.5 °C.

i) Calculate the pressure coefficient (Cp) values on both upper & lower surfaces of the airfoil.

ii) How do you determine the sign of calculated Cp values?

iii) Estimate the lift coefficient of the airfoil.

iv) What are your suggestions to improve the accuracy of the estimated lift coefficient?

[7.0 Marks]

Q3. a) Briefly illustrate the adverse effects experienced by a small aircraft which flies proximity to a large aircraft.

[2.0 Marks]

b) The wings of a military aircraft are made of NACA 2412 airfoil section. The tapered planform wings have a total span of 21 m; while the root chord length and the tip chord length are 6.0 m and 1.2 m respectively. The aircraft having 45500 kg of gross weight cruises at an altitude of 11 km with a constant speed of 875 km/h.

The lift coefficient and the drag coefficient variations for the NACA 2412 as a function of Angle of Attack (AoA) are presented in Table Q3. Further the induced drag factor as a function of taper ratio and the aspect ratio is given in Fig. Q3 and assume $\delta = \tau$. If the total power requirement of the aircraft is 5.5 MW, determine;

i) The required AoA during the cruise,

ii) The induced drag and the skin friction drag acted on the aircraft,

iii) The wave drag acted on the aircraft.

[10.0 Marks]

Q4. a) Comment on the statement "Increasing the distance between the center of gravity and aerodynamic center is not a viable option to enhance the stability of an aircraft".

[2.0 Marks]

b) An aircraft has been subjected to oscillation of its angle of attack due to an environmental disturbance. Considering a moment in which the nose of the aircraft goes down, explain how an opposing pitch up moment is being generated to damp out said pitch oscillation.

[3.0 Marks]

c) The pilot has changed the elevator deflection by an amount of δm when an aircraft performs a pure longitudinal flight with an equilibrium angle of attack α_e and equilibrium velocity V_e . Determine expressions with usual notation;

i) Change in equilibrium angles of attack, $\Delta\alpha_e$,

ii) Change in equilibrium velocity, ΔV_e.

[5.0 Marks]

d) Using the results from part Q4.(c) above, demonstrate that the negative control surface deflections generate positive aircraft responses.

[2.0 Marks]

Q5. a) Differentiate between the "Airworthiness code" and the "Acceptable means of compliance" in relation to airworthiness regulations.

[2.0 Marks]

b) Briefly describe "Safe life" and "Fail safe" design strategies in relation to aircraft design.

[2.0 Marks]

c) Derive an expression for a load factor when an aircraft performs pitch-up moment. Hence describe how a zero gravity condition could be generated during a flight

[4.0 Marks]

d) A medium size aircraft cruises with a speed 175 ms^{-1} at standard sea level conditions having a maximum take-off weight of 4500 kg. The reference area for the wings is 19.33 m^2 and the maximum lift coefficient is 2.3. According to JAR 23 airworthiness regulation, the allowable load factor is +6.2.

i) Calculate the stalling speed and the corner velocity of the aircraft.

ii) If the diving velocity is 1.2 times the cruising speed, plot how the load factor varies with velocity of the aircraft.

[4.0 Marks]

Data and Formulae sheet for Aerospace Engineering

(All symbols indicate usual notations)

a.) For sea-level atmospheric conditions use followings:

Static pressure (P_0)	=	101325 Pa
Temperature (T_0)	=	288.15 K
Density (ρ_0)	=	1.225 kg.m^{-3}
Acceleration due to gravity (g_0)	=	9.81 m.s^{-2}
Specific heat ratio (γ)	=	1.4
Real gas constant (R_g)	=	287 J.kg^{-1}.K^{-1}

b.) In an ISA the static pressure (*P*) and the temperature (*T*) are given by,

i) Below 11 km:

$$P = P_0\left(1 - 2.2558\times10^{-5}h\right)^{5.2559} \text{ N.m}^{-2},$$

$$T = T_0 - 0.0065h \text{ K},$$

ii) From 11 km to 20 km:

$$ln\left(\frac{P}{P_b}\right) = -\frac{g_0}{RT_b}(h - h_b)$$

$$T = Const.$$

Where *h* is measured in meters, note 1 ft = 0.3048 m.

c.) For a steady, adiabatic, isentropic and inviscid flow, the total pressure (P_T), free stream pressure (P_∞) and free stream Mach number (M_∞) are related as,

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

d.) Atmospheric air can be treated as a perfect gas,

$$P = \rho R_g T$$

Speed of sound $a = \sqrt{\gamma RT}$.

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

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

Table Q2: Manometer pressure readings at AoA 4°

Pressure Tap Position	**Water Manometer Readings (in inches)**	
	Upper Surface	**Lower Surface**
0	0.6	0.6
0.075	2.7	0.6
0.1	2.6	0.7
0.2	2.5	0.7
0.3	2.3	0.8
0.4	2.2	0.8
0.5	2.1	0.9
0.6	1.5	0.9
0.7	1.4	0.9
0.8	1.2	0.9
1.0	1.0	1.0

Note :1 inch = 0.0254 m

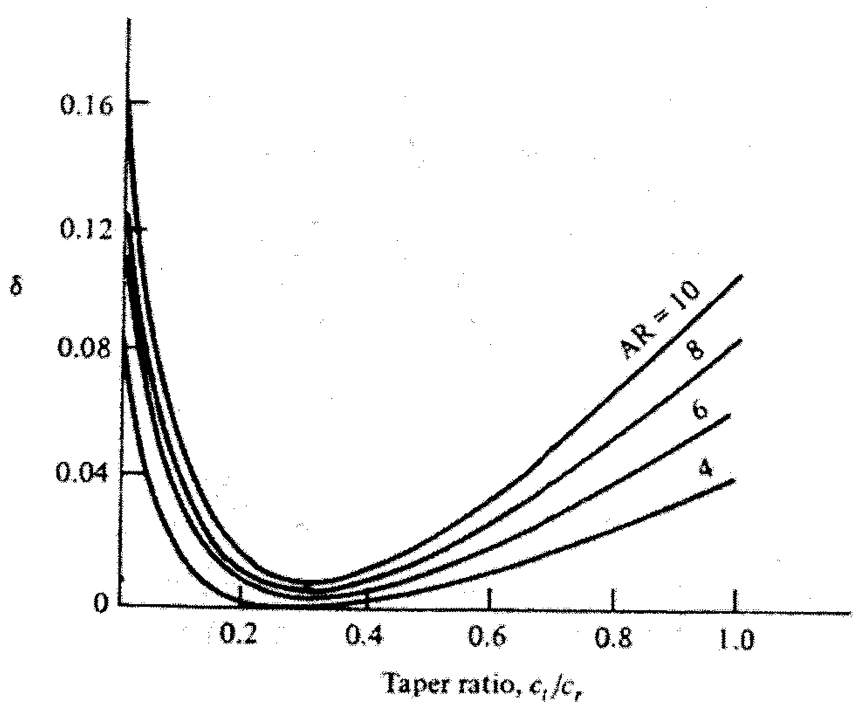

Fig. Q3: Induced drag factor variation

Table Q3: NACA 2412 airfoil data

Angle of Attack (AoA) (degrees)	Lift coefficient - c_ℓ	Drag coefficient - c_d
-4	-0.12	0.008
-2	0.12	0.006
0	0.36	0.006
2	0.6	0.006
4	0.84	0.007
6	1.08	0.0075
8	1.32	0.0092
10	1.56	0.0098
12	1.8	0.012