UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: May 2023

Module Number: ME7217 **Module Name: Aerospace Engineering**

[Three Hours]

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

NOTE:
Required data and formulae are given in page 3.
Use carefully labeled sketches to support your answers where necessary.
You may make additional assumptions, but clearly state them in your answers.

Q1. a) Show all the key control surfaces on a schematic diagram of an aircraft. Also shortly describe the functions of each of them.

[3.0 Marks]

b) Draw the variation of lift coefficient and moment coefficient with angle of attack for the following airfoil shapes.

i) NACA 0016
ii) NACA 4412

[4.0 Marks]

c) Consider an airfoil with chord length and the running distance 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:

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

$$C_{P2} = -2.2277 + 2.2777\left(\frac{x}{c}\right)^2 \text{ for } 0.1 \le x/c \le 1,$$

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

i) Which expressions show variations over the upper surface of the airfoil? Explain your answer. [2.0 Marks]

ii) Estimate the lift coefficient of the airfoil.

[3.0 Marks]

Q2. a) How can the flying speed and flying altitude be determined in an aircraft?

[1.0 Mark]

b) Differentiate between the absolute altitude and geometric altitude. With usual notations derive an expression for pressure variation with in the first sub layer of the stratosphere of the International Standard Atmosphere (ISA).

[5.5 Marks]

c) An aircraft cruising at 16.5 km in ISA, gives a pitot pressure reading of 0.8312 bar. Estimate the flying Mach number and the cruising speed of the aircraft.

[5.5 Marks]

Q3. a) Explain: "Appropriate gaps have to be maintained between consecutive take-offs in an airport".

[2.0 Marks]

b) Describe stalling mechanism in an aircraft.

[2.0 Marks]

c) Comment on 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 with usual notations is given 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 constant local lift coefficient throughout its span.

[5.0 Marks]

Q4. a) Describe requirements to be satisfied to maintain a pure longitudinal flight.

[3.0 Marks]

b) An aircraft performs a pure longitudinal flight with an equilibrium angle of attack (AoA) α_e . Suppose due to a sudden guest its AoA has been changed. Describe how the original AoA is restored in each of following cases.

i) α_e is increased by $\delta\alpha$,

ii) α_e is decreased by $\delta\alpha$.

[2.5 Marks]

c) Explain "Increasing the distance between the aerodynamic center and the center of gravity reduces the fuel economy of an aircraft."

[3.0 Marks]

d) Describe "pitch rate damping" mechanism of an aircraft.

[3.5 Marks]

Q5. Consider an aircraft having following characteristics.

Table Q5: Aircraft Data

Wing Area	50 m2	AR	7
e	0.89	Weight	110,000 N
CD0	0.035	Thrust	30,000 N

a) At sea-level conditions, calculate the minimum power required by the aircraft

[5.0 Marks]

b) Determine the Maximum Rate of Climb (RoC) at sea level conditions and at 4 km Altitude (where the density of air is 0.81935 kgm−3).

[5.0 Marks]

c) Estimate absolute ceiling height for the aircraft assuming linear variation of RoC.

[2.0 Marks]

Data and Formulae sheet

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}
Dynamic viscosity	=	1.75 × 10^{-5} kg/ms

b.) In an ISA below 11 km, the static pressure (*P*) and the temperature (*T*) are given by,

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

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

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

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

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

$$P = \rho R_g T$$

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